American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

Amendment 1: Test Site Validation

C63®

Accredited Standards Committee C63® — Electromagnetic Compatibility

Accredited by the
American National Standards Institute

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ANSI C63.4a-2017
(Amendment to ANSI C63.4-2014)

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Secretariat
Institute of Electrical and Electronics Engineers, Inc.

Approved 15 September 2017
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C63®

Abstract: U.S. consensus standard methods are specified in Annex D of this amendment for validating standard test sites and alternative test sites used for measurement of radiated radio-frequency (RF) signals and noise emitted from electrical and electronic devices in the frequency range of 30 MHz to 1 GHz. In addition, various updates are made to equations in 4.5, Annex F, Annex G, and Annex N.

Keywords: Annex D, ANSI C63.4, normalized site attenuation, NSA, site attenuation, site validation

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Introduction

This introduction is not part of ANSI C63.4a-2017, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz—Amendment 1: Test Site Validation.

Following several recent interpretation requests, in late 2015 the ASC C63® Main Committee directed ASC C63® Subcommittee 1 to prepare a fast-track amendment primarily concerned with Annex D on test site validations of the 2014 edition of ANSI C63.4 (ANSI C63.4-2014). The scope of this fast-track amendment project was limited mainly to topics raised by the interpretation requests. At the time that this amendment was developed, a separate routine maintenance project for ANSI C63.4-2014 overall was also in progress in ASC C63® Subcommittee 1; other issues and topics outside the scope of this amendment project may be considered in that ANSI C63.4 overall review and revision project. This amendment forms a permanent addition to ANSI C63.4, and as such it is subject to the ASC C63® normal maintenance procedures for any future updates. The contents of this amendment are not expected to be changed by the other ANSI C63.4 revision project that is ongoing at the time of preparation of this document.

This amendment mainly updates the test site validation procedures in Annex D in ANSI C63.4-2014 and corrects equations in several annexes. At the May 2017 meeting of ASC C63®, another addition to the amendment was approved. This addition corrected the value of the separation distance between the receiving antenna and the equipment under test. The latter correction brought it back to what was in previous editions of ANSI C63.4. Hence, this amendment combines changes in the Annex D test site evaluation, corrections to equations in annexes, and a correction to a separation distance value in the main body of the standard.

The more significant updates to Annex D consist of the following:

— Corrected the equation for calculating the measured NSA value [i.e., Equation (D.1) of ANSI C63.4-2014]

— Added text to clarify the single-position NSA geometry for validation of standard test sites, which previously was indicated mainly by the measurement setup figures and NSA tables

— Added requirements for maximum frequency step size for both the discrete frequency method and the swept frequency method; also quantified the existing requirement for the receive antenna height scan rate for the swept frequency method

— For the swept frequency method, added the requirement to report in tabular format those measured NSA values that are within 1 dB of the site acceptability criterion

— Removed the provision from D.3 for moving the antenna inward from the periphery for the left and right positions in horizontal polarization

— Added equations to be used for calculating theoretical NSA for an ideal site, which can be used for frequencies and/or geometries other than those listed in the tables

— Expanded the tables of theoretical NSA for an ideal site by adding values for a 5 m measurement distance (for example, CISPR 32:2015 [B53] allows a 5 m measurement distance),[a] for greater transmit antenna heights (for validating test volumes taller than 2 m), and for the frequency increments specified in the measurement procedures subclauses (i.e., D.4 and D.5)

— Updated the figures and added a top-view figure for vertical polarization [i.e., Figure D.3 b)], depicting the re-orientations of the transmit antenna and the receive antenna for the left and right positions of the transmit antenna

[a] Numbers in brackets correspond to those of the bibliography in Annex O of ANSI C63.4-2014.

In addition to the Annex D changes, updates to various equations in Annex F, Annex G, and Annex N and the antenna to equipment under test separation distance value in 4.5 of ANSI C63.4-2014 are provided in this amendment.

Based on a recently issued interpretation,[b] the measurement distance criterion for electric field strength measurements (1 GHz to 40 GHz) with horn antennas in 4.5.5 (and in table footnotes in 4.5.1) of ANSI C63.4-2014 is modified to as it was in the 1992 edition of ANSI C63.4, and consistent with CISPR 16-1-4[c] and CISPR 16-2-3 [B14].

[b] Clause 4.5 Horn antenna aperture, June 2017 (http://c63.org/documents/misc/posting/new_interpretations.htm).

[c] Information on references can be found in Clause 2 of ANSI C63.4-2014.

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American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

Amendment 1: Test Site Validation

NOTE 1—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE 1 will not be carried over into future editions because the changes will be incorporated into the base standard.

NOTE 2—In this document, a table note (a note to a table) is informative, and a table footnote is normative. A table note is set immediately following the table to which it belongs, enclosed within the boxed table, above the bottom border of the table. General notes apply to the entire table and are introduced by "NOTE—" set in all, uppercase letters. A table footnote always contains normative information. A table footnote is set outside of the boxed table to which it belongs, immediately below the bottom border. Table footnotes are marked with lowercase letters starting with "a" for each table.

NOTE—This amendment mainly updates the test validation procedures in Annex D in C63.4-2014 and corrects equations in several annexes. At the May 2017 meeting of ASC C63®, another addition to the amendment was approved. This addition corrected the value of the separation distance between the receiving antenna and the equipment under test. The latter correction brought it back to what was in previous editions of ANSI C63.4. Hence, this amendment combines changes in the Annex D test site evaluation, corrections to equations in annexes, and a correction to the antenna to equipment under test separation distance value in 4.5 of the main body of the standard.

4.5 Antennas

4.5.1 General considerations

Table 1—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (and their frequency ranges of operation)

Replace footnote g in Table 1 as follows:

[g] The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh distance (i.e., $R_{\mathrm{m}} = D^2 / 2\lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

Table 2—Antennas (and their frequency ranges of operation) for use in making final compliance measurements on devices

Replace footnote f in Table 2 as follows:

[f] The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh distance (i.e., $R_{\mathrm{m}} = D^2 / 2\lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

Table 3—Antennas (and their frequency ranges of operation) for use in performing test site validation measurements

Replace footnote g in Table 3 as follows:

[g] The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh distance (i.e., $R_{\mathrm{m}} = D^2 / 2\lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

4.5.5 Electric field measurements (1 GHz to 40 GHz)

Replace the second paragraph of 4.5.5 as follows:

The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in meters) is equal to or greater than the Rayleigh distance (i.e., $R_{\mathrm{m}} = D^2 / 2\lambda$), where D is the largest dimension of the antenna aperture (in meters) and λ is the free-space wavelength (in meters) at the frequency of measurement. In case of dispute, measurements made with a standard-gain horn antenna shall take precedence.

Changes to Annex D include the following:

- ***New Table D.1 is added in D.1, and new Table D.2 is added in D.2.4.***
- ***Subclauses D.2.1 to D.2.4 are added in D.2.***
- ***In D.2.1 (formerly D.2), Equation (D.1) is updated and replaced by Equation (D.1) and Equation (D.2). The existing Equation (D.2) is renumbered as Equation (D.3).***
- ***New subclauses D.3.1 to D.3.4 are added in D.3.***
- ***The NOTE at the end of the existing D.3 of ANSI C63.4-2014 is moved to the end of D.3.3.***
- ***The last paragraph (before the NOTE) of the existing D.3 of ANSI C63.4-2014 is updated and moved to the new D.2.5.***
- ***Insert new D.7, and renumber the existing D.7 of ANSI C63.4-2014 as D.8.***
- ***The existing Table D.1 of ANSI C63.4-2014 is split into four tables as Table D.3 through Table D.6 (see associated editing instructions in D.8).***
- ***The existing Table D.2 through Table D.7 of ANSI C63.4-2014 are renumbered (also with updates) as Table D.7 through Table D.12 (see associated editing instructions in D.8).***
- ***Footnotes are inserted, and any following this annex should be renumbered accordingly.***

Replace Annex D as follows:

Annex D

(normative)

Validation of radiated emission test sites (30 MHz to 1 GHz)

NOTE—In this annex, for contiguous readability of body text, all tables (except Table D.1 and Table D.2) and figures are placed in their own subclause following the text subclauses, i.e., entitled **D.8 Tables and figures for Annex D**.

D.1 Theoretical NSA

Subclause 5.4.4.1 (General requirements) of ANSI C63.4-2014 describes what normalized site attenuation (NSA) for site validation is and how it is evaluated.[27] The theoretical NSA values for an ideal site for the most frequently used measurement distances and antenna types are shown in Table D.3 through Table D.8 (see D.8).[28] The theoretical NSA was developed and calculated in Smith et al. [B28], and the equations used for calculating the theoretical NSA for an ideal site are provided in D.7. Mutual impedance correction factors for NSA data obtained with tuned dipole antennas, shown in Table D.9 (see D.8), were developed in Smith et al. [B28], and were subsequently revised in Berry et al. [B8] and Pate [B26]. Table D.1 gives a summary of the contents of the tables of theoretical NSA values in D.8.

27 The site validation process using measured *GSCF* values obtained per Annex I of ANSI C63.5-2017 is mathematically equivalent to comparing the measured site attenuation results directly to the results from the antenna calibration site (Chen [B54]). The site validation process using *GSCF* values for biconical dipole antennas per Annex G of ANSI C63.5-2017, or ΔAF_{TOT} for tuned dipole antennas from Table D.8 (see D.8), is functionally equivalent to comparing the measured site attenuation results to numerically-derived site attenuation values for an ideal site. Notwithstanding the preceding sentences, the only acceptable methods for demonstrating compliance with the NSA requirements of ANSI C63.4 are those detailed in D.1 through D.7.

28 Some regulatory and/or purchasing agencies may not accept the use of a 5 m separation distance for measurements of radiated emissions.

Table D.1—Summary of tables of NSA theoretical values given in D.8

Table number	Antenna type	Antenna polarization	Measurement method	h_1, m
Table D.3	broadband	horizontal	discrete frequency	1.0, 2.0, 2.5, 3.0
Table D.4	broadband	vertical	discrete frequency	1.0, 1.5, 2.0, 2.5
Table D.5	broadband	horizontal	swept frequency	1.0, 2.0, 2.5, 3.0
Table D.6	broadband	vertical	swept frequency	1.0, 1.5, 2.0, 2.5
Table D.7	tuned dipoles	horizontal	discrete frequency	2.0
Table D.8	tuned dipoles	vertical	discrete frequency	2.75
NOTE 1—Discrete frequency measurement method—see D.4. NOTE 2—Swept frequency measurement method—see D.5. NOTE 3—Measurement distance R, m: 3, 5, 10, 30.				

The symbols used in the tables of NSA values in D.8 are defined as follows:

R is the horizontal separation distance between the projection of the reference points of the transmit antenna and the receive antenna on the reference ground plane (m)
h_1 is the height of the center of the transmit antenna above the reference ground plane (m)
h_2 is the height of the center of the receive antenna above the reference ground plane (m); in the measurement procedure, h_2 is varied, and the maximum received signal in the h_2 height scan range is used in the NSA calculations
f_M frequency (in megahertz)
A_N is theoretical NSA; see Equation (D.4) in D.7

Table D.3 through Table D.6 are used for broadband antennas (such as biconical and LPDA antennas), aligned horizontally and vertically, respectively, relative to the reference ground plane, at a standard test site or an alternative test site. Table D.7 and Table D.8 are for tuned dipoles, aligned horizontally and vertically, respectively, relative to the reference ground plane, at a standard test site. Note that the transmit antenna and receive antenna heights in Table D.8 are specified to keep the lowest tip of the dipole element spaced 25 cm or more from the reference ground plane.

NSA values for frequencies other than those shown in the tables shall be calculated using linear interpolation between the tabulated values; alternatively, the equations for theoretical NSA for an ideal site provided in D.7 may be used.

D.2 NSA measurements

D.2.1 General

Two antennas are set up on the test site in a specific geometry as illustrated in Figure D.1 and Figure D.2 (see D.8); Figure D.2 is an illustration for dipoles only–the actual geometry requirements are in D.2.3. The NSA procedure requires two different measurements of the voltage received V_R. The first reading of V_R is with the two coaxial cables, including any added impedance matching attenuators whose insertion losses are not included with the antenna factors (if used), disconnected from the two antennas and connected to each other via an adapter. The second reading of V_R is taken with the coaxial cables, including any added impedance matching attenuators (if used), reconnected to their respective antennas and the maximum signal measured with the receive antenna scanned in height (Heirman [B20]). For both of these measurements, the signal generator voltage level V_I is kept constant. The first reading of V_R is called V_{Direct} and the second reading is called V_{Site}. These voltages are used in Equation (D.1) or Equation (D.2) to calculate the measured NSA (A_N):

$$A_{\mathrm{N}} = V_{\mathrm{Direct}} - V_{\mathrm{Site}} - AF_{\mathrm{T}} - AF_{\mathrm{R}} - \Delta AF_{\mathrm{TOT}}, \quad \text{for tuned dipoles} \tag{D.1}$$

$$A_{\mathrm{N}} = V_{\mathrm{Direct}} - V_{\mathrm{Site}} - AF_{\mathrm{T}} - AF_{\mathrm{R}} - GSCF, \quad \text{for all other antennas} \tag{D.2}$$

where

AF_{T} is the antenna factor of transmit antenna (dB/m)
AF_{R} is the antenna factor of receive antenna (dB/m)
ΔAF_{TOT} is the mutual impedance correction factor (dB)
$GSCF$ is the geometry-specific correction factor (dB)

The latter antenna parameters are described in D.2.2. The difference of the first two terms in Equation (D.1) and Equation (D.2), i.e., $V_{\mathrm{Direct}} - V_{\mathrm{Site}}$, represents the conventional (classical) site attenuation (CSA).[29] V_{Direct} (in dBμV) is given by Equation (D.3):

$$V_{\mathrm{Direct}} = V_{\mathrm{I}} - C_{\mathrm{T}} - C_{\mathrm{R}} \tag{D.3}$$

where C_{T} and C_{R} (in dB) are the cable losses that do not need to be measured separately, and V_{I} (in dBμV) is the signal generator output voltage.

D.2.2 Antennas

The parameters AF_{T} and AF_{R} in Equation (D.1) and Equation (D.2) are determined using the applicable antenna calibration process as specified in ANSI C63.5. For Equation (D.1), the mutual impedance correction factor ΔAF_{TOT} (see Table D.9 in D.8) applies only to the site geometry of 3 m separation, for both horizontal and vertical polarizations, when using tuned dipoles. The mutual impedance correction factor $\Delta AF_{\mathrm{TOT}} = 0$ for all other geometries using tuned dipoles. For Equation (D.2), the appropriate *GSCF* values, as determined per ANSI C63.5, shall be used; see also the considerations in NOTE 2 about use of Annex G and Annex I of ANSI C63.5-2017.

NOTE 1—Users are cautioned that the determination of the appropriate *GSCF* values using the methods described in ANSI C63.5 is a complex undertaking, and that these factors are dependent on the exact type of antenna used.

NOTE 2—The theoretical values for *GSCF* in Annex G of ANSI C63.5-2017 apply only for biconical antennas that comply with the dimensional and other conditions stated within that annex. If such biconical antennas are used for performing NSA measurements at heights that are not covered in that Annex G (e.g., 2.5 m for vertical, and 3 m for horizontal), appropriate *GSCF* values are determined using the procedure in Annex I of ANSI C63.5-2017. For biconical antennas that differ from the dimensional and other conditions stated in Annex G of ANSI C63.5-2017, and for LPDA antennas and/or hybrid antennas, *GSCF* values are determined using the procedure in Annex I of ANSI C63.5-2017.

Linearly-polarized antennas, with calibrated antenna factors, are required for NSA measurements. Antenna factors shall be calibrated using the Standard Site Method (SSM) specified in ANSI C63.5, and the measurements involved shall be traceable to a national standard. Antennas shall be calibrated as a pair (i.e., transmit antenna and receive antenna shall be calibrated together), in accordance with 4.4.2 of ANSI C63.5-2017.

Antenna factors usually account for losses in the balun. If a separate balun or any integrally associated attenuators, or both, are used, their effects shall be included in the antenna calibration results.

The receive antenna and the transmit antenna shall be identical (i.e., same manufacturer and model number; or the antenna factors of the individually calibrated antennas shall differ from each other within 1 dB at each calibration frequency), and shall be of the types specified in Table 3 (see 4.5.1 of ANSI C63.4-2014) for use in performing test site validation measurements. The design of a tuned dipole reference antenna is described in ANSI C63.5 (see also the NOTE in 4.5.4 of ANSI C63.4-2014).

[29] The terms “classical site attenuation” and “conventional site attenuation” have been used in the literature (see, e.g., Heirman [B19]) to refer to propagation loss measurements using a pair of tuned dipole antennas at a ground-plane site, but without normalizing by antenna factors as is done for NSA results. Another term used is “site insertion loss” (SIL).

D.2.3 Measurement methods

NSA shall be measured using one or both of the following procedures:

- The discrete frequency measurement method — see D.4 (for use with tuned dipole antennas or broadband antennas)
- The swept frequency measurement method — see D.5

The swept frequency method may be used only with broadband antennas, but tuned dipoles may be used at specific (fixed) frequencies in case spot checks or troubleshooting of such NSA values becomes necessary (i.e., for standard test sites only; tuned dipoles shall not be used for NSA validation of alternative test sites – see D.3.2).

For tuned dipoles, Figure D.1 illustrates the horizontal polarization NSA measurement geometry and Figure D.2 illustrates the vertical polarization NSA measurement geometry (assuming that the dipoles are tuned for all frequencies down to 30 MHz; see figures in D.8). The limiting factor of maintaining at least a 25 cm clearance between the reference ground plane and the lower tip of the receive antenna and the transmit antenna is addressed by fixing the transmit antenna height at 2.75 m and restricting the downward travel of the receive antenna. These restrictions are stated explicitly by the lower scan-height limit in Table D.8 (see D.8).

For NSA measurements with broadband antennas, the horizontal polarization geometry is also illustrated by Figure D.1. For vertical polarization NSA measurements with broadband antennas, scan height restrictions usually are not required because of the much smaller fixed dimensions of a broadband antenna compared with a tuned dipole, especially between 30 MHz and 80 MHz. Using linearly-polarized broadband antennas allows minimum transmit antenna and receive antenna heights of 1 m (see also N.2 in Annex N of ANSI C63.4-2014 for dimensional restrictions on hybrid antennas). The requirement for a minimum clearance of 25 cm between the reference ground plane and the lower tips of the receive antenna and the transmit antenna also applies for broadband antennas.

NOTE 1—For both the discrete frequency and the swept frequency methods, an impedance mismatch at the output of the signal source or at the input of the EMI receiver or spectrum analyzer may result in cable reflections that could cause errors exceeding the NSA tolerance. This can be avoided by use of padding attenuators of 10 dB, i.e., one at the antenna end of the transmit antenna cable and one at the receiver end of the receive antenna cable, for both V_{Direct} and V_{Site} measurements. Attenuator values of 6 dB are often adequate, and values as low as 3 dB can sometimes be used.

NOTE 2—For vertically polarized antennas, it is especially important to maintain cables leaving the antennas in the same horizontal plane as the center of the antenna directly behind the antenna for a minimum distance of 1 m. Use of ferrite beads on both the transmit antenna and the receive antenna cables close to the antennas can help to eliminate common-mode signals that can contribute to measurement errors.

D.2.4 Single-position NSA measurements for standard test sites

A standard test site[30] shall be validated by measuring NSA with the transmit antenna and the receive antenna separated by the measurement distance, for both horizontal and vertical antenna polarizations, for a single location of the antenna pair above the reference ground plane. Basic setups are shown in Figure D.1 and Figure D.2 (see D.8), for horizontal polarization and vertical polarization of the antenna pair, respectively. The test site shall be evaluated in the exact measurement geometry (i.e., locations of transmit antenna and receive antenna on the site) that is used for subsequent product testing. The transmit antenna shall be placed at the EUT location used during subsequent radiated emission measurements (e.g., at the center of the turntable), while the receive antenna shall be positioned at a location that is separated from the transmit antenna location by the measurement distance; see also the site descriptions in 5.4.1, and the site layout in Figure 5 of 5.7 (both in ANSI C63.4-2014). The transmit antenna and the receive antenna shall be placed in the same polarization, and oriented towards each other. Antenna heights above the ground plane per polarization and antenna type for single-position NSA standard test site validation are as shown in Table D.2.

[30] Per 5.4.1 of ANSI C63.4-2014, a standard test site is "an open, flat, level area that is clear of overhead wires and reflecting structures and is sufficiently large to permit measuring antenna placement at the specified distance. This is commonly called an OATS when the ground is covered with conductive material." Per Clause 3 of ANSI C63.7-2015 [B55], a standard test site is an "open-area test site (OATS) that does not incorporate weather-protection (or other) structures above the surface of its ground plane."

Table D.2—Antenna heights for single-position NSA measurements

Antenna type	Polarization	h_1, m	h_2, m
Broadband	Horizontal	1 and 2	1 to 4
Broadband	Vertical	1 and 1.5	1 to 4
Tuned dipole	Horizontal	2	1 to 4
Tuned dipole	Vertical	2.75	see Table D.8

D.2.5 Site acceptability criterion

A test site is considered suitable for performing radiated emission measurements in 30 MHz to 1 GHz if the results of all NSA measurements described in this annex meet the requirements of 5.4.4.2, and the reference ground plane of the test site complies with the requirements of 5.4.3 (subclause numbers are per ANSI C63.4-2014).

D.3 NSA for alternative test sites

D.3.1 General

For an alternative test site (for example, a weather-protected OATS or a semi-anechoic chamber; see other descriptions in 5.4.2 of ANSI C63.4-2014), a single-position NSA measurement (i.e., per D.2.4) is insufficient to pick up possible reflections from the construction materials or the RF-absorbing materials covering the walls and ceiling of the test site, or weather-protection coverings for an OATS.

A weather-protected OATS, regardless whether the weather-protection structure covers only a portion of (e.g., the turntable area) or the entire OATS, is not considered a standard test site, because the potential effects of the covering structure cannot be determined without performing volumetric NSA measurements.[31] Therefore, each weather-protected OATS shall be validated using the positions and geometries described in D.3.3 and D.3.4.

Different from the single-position NSA measurements used for a standard test site (i.e., site as described in 5.4.1 of ANSI C63.4-2014; see also D.2.4), alternative test sites require NSA measurements made with the transmit antenna and the receive antenna placed at multiple equidistant positions on the reference ground plane, as described in D.3.3 and D.3.4.

For an alternative test site, a “validated test volume” (i.e., in the form of an imaginary cylinder) is defined as that volume traced out by the largest equipment or system to be tested as it is rotated about its center location through 360° (e.g., using a turntable). This is the “test volume to be validated” using the positions and geometries described in D.3.3 and D.3.4.

For evaluating a test site, the transmit antenna shall be placed at various positions within the test volume to be validated with both horizontal and vertical polarizations (see the illustrations in Figure D.3 and Figure D.4, and German [B17]). This can require a maximum of 20 separate site attenuation measurements; that is, five positions in the horizontal plane (center, left, right, front, and rear, measured with respect to the center and a line drawn from the center to the position of the measuring antenna), for two antenna polarizations (horizontal and vertical) and for a maximum of two transmit antenna heights per polarization.

[31] The term “volumetric NSA” refers to NSA measurements for the positions and geometries specified in D.3.3 and D.3.4.

D.3.2 Antennas

NSA measurements for an alternative site shall be performed with broadband antennas; i.e., tuned dipole antennas cannot be used for validating an alternative test site.

NOTE—Due to their dimensions at low frequencies, tuned dipoles cannot be used in all the various positions required for validating an alternative site, because the antenna tips can be too close to the ground plane, or to the wall or ceiling absorbers, or to the weather-protection covering.

D.3.3 Measurement geometries

a) The required minimum two transmit antenna heights for site validation NSA measurements shall be selected in accordance with the following provisions.

   1) For both horizontal and vertical polarizations, one of the two required transmit antenna heights is 1 m.

   2) The second of the minimum two transmit antenna heights is determined by the height of the test volume to be validated.

      i) For horizontal polarization measurements, the second transmit antenna height shall be set to the height of the test volume to be validated (e.g., 2 m, 2.5 m, or 3 m), with a minimum transmit antenna height of 2 m. The maximum height of the transmit antenna shall be 3 m or less.

      NOTE 1—For the purposes of this document EUTs are not expected to be taller than 3 m; therefore, the second antenna height for site validation need not be greater than 3 m.

      ii) For vertical polarization measurements, the second transmit antenna height shall be set to be 0.5 m lower than the transmit antenna height selected in a) 2) i) for the horizontal polarization measurements, with a minimum transmit antenna height of 1.5 m.

   3) For subsequent EUT radiated emission measurements, the maximum EUT height, relative to the reference ground plane, shall not exceed the height of the validated test volume.

   EXAMPLE—If the height of the test volume to be validated is 3 m, for an example site with 10 m measurement distance, the transmit antenna heights for horizontal polarization measurements are 1 m and 3 m (i.e., per Table D.3 or Table D.5); for vertical polarization measurements the transmit antenna heights are 1 m and 2.5 m (i.e., per Table D.4 or Table D.6).

b) Separation (measurement) distances *R* shall be determined relative to the projections on the ground plane of the reference points of the transmit antenna and the receive antenna. The separation distance *R* shall be maintained constant for all measurement positions according to Table D.3 through Table D.6. This fixed-separation condition requires that the receive antenna be moved along the longitudinal centerline in the directions shown in Figure D.3 through Figure D.6, so as to maintain the separation distance *R* constant for all transmit antenna positions.

c) The transmit antenna and the receive antenna shall be aligned with the antenna elements parallel to each other and orthogonal to the measurement axis. Therefore, for all transmit antenna positions off the longitudinal centerline, for both horizontal and vertical polarizations, both antennas shall be rotated about their vertical axes so that the antenna elements remain parallel to each other while maintaining the correct polarization.

d) For both horizontal and vertical polarizations, the off-center positions of the transmit antenna are at the periphery of the test volume (i.e., the reference point of the antenna is located at the periphery of the test volume).

e) For vertical polarization measurements, the distance between the floor and each of the lower tips of the transmit antenna and the receive antenna shall be greater than or equal to 25 cm.

f) No portion of the transmit antenna or the receive antenna shall be closer than 25 cm to the construction or absorbing materials on the four walls or ceiling in any of the possible positions and polarizations of the two antennas. This requirement places an upper limit on the extent of the validated test volume (i.e., its diameter and its height) at alternative test sites.

NOTE 2—Radiated emission sources located near dielectric interfaces, such as absorbing pyramids or ferrite tiles, have been shown to have variations in current distribution that can affect the radiation properties of the source at that location (Pate [B26]).

D.3.4 Reduced number of NSA measurement positions

The number of required measurement positions may be reduced under the following conditions:

a) The rear position for vertical and horizontal polarization measurements may be omitted if the closest point of the construction or absorbing material is at a distance of greater than 1 m from the rear boundary of the test volume (see NOTE 2 in D.3.3).

b) The horizontal polarization measurements at the left and right positions may be omitted if the length of the largest usable elements of the transmit antenna covers 90% or more of the diameter of the test volume.

c) If the test volume is no larger than 1.2 m in diameter by 1.5 m in height (measured from the ground plane), horizontal polarization measurements are required only at the center, front, and rear positions, and for both the 1 m and 2 m heights. The rear position may be omitted if the condition of D.3.4 a) applies. Therefore a minimum of eight measurement geometries are required for the given test volume, as follows:

    1) Vertical polarization: one height; left, center, right, and front positions (see Figure D.5 in D.8)

    2) Horizontal polarization: two heights; center and front positions (see Figure D.6 in D.8)

D.4 Site attenuation using discrete frequencies

For the discrete frequency method, specific frequencies are measured in turn. At each frequency the receive antenna is moved over the height range given in the appropriate table in D.8 to maximize the received signal. These measured parameter values are inserted in Equation (D.1) or Equation (D.2) (see D.2.1) to obtain the measured NSA. The discrete frequency method involves a worksheet approach to record the data, calculate the measured NSA, and then compare it with the theoretical NSA (Heirman [B19]). The sample worksheet serves the following purposes:

— Sequences the site attenuation measurements

— Directs the application of various corrections

— Provides a method for comparing deviations of the measured NSA data from the NSA for an ideal site

Table D.10 contains the recommended worksheet for comparing the measured NSA results with the NSA values for the ideal site obtained from Table D.3 and Table D.4 (for broadband antennas), or from Table D.7 and Table D.8 (for tuned dipoles). The worksheet entries are used for solving Equation (D.1) or Equation (D.2). Descriptions of the entries for each column are as given in Table D.11. Table D.12 gives an example of the use of the worksheet, which considers a 3 m separation horizontal site attenuation measurement using tuned dipoles at 80 MHz.

When using the discrete frequency method, the frequency step size shall be less than or equal to 5 MHz from 30 MHz to 200 MHz, and shall be less than or equal to 25 MHz from 200 MHz to 1000 MHz. At frequencies other than those listed in the tables in D.8, the NSA values shall be calculated by linear interpolation between two adjacent tabulated values, as described in D.1; alternatively, the equations for theoretical NSA for an ideal site provided in D.7 may be used.

D.5 Site attenuation using swept frequencies

In the swept frequency method, both the transmit antenna height and the frequency are scanned or stepped over the required ranges. The swept frequency method shall be used only with broadband antennas.

Typical instruments used for performing NSA measurements with the swept frequency method are:

- Vector network analyzer;
- Spectrum analyzer or EMI receiver, equipped either with a tracking generator, or combined with a signal generator that is able to step through the required frequency range and is synchronized with the tuning frequency of the analyzer / receiver (e.g., by means of a computer controlling both instruments).[32]

When using the swept frequency method, the frequency step size shall be less than or equal to 2 MHz from 30 MHz to 200 MHz, and shall be less than or equal to 5 MHz from 200 MHz to 1000 MHz. At frequencies other than those in the tables in D.8, the NSA values shall be calculated by linear interpolation between two adjacent tabulated values, as described in D.1; alternatively, the equations for theoretical NSA for an ideal site provided in D.7 may be used.

The receive antenna maximum height change shall be less than or equal to 5 cm during one complete frequency sweep of the instrumentation. If the receive antenna is stepped in height, rather than swept continuously, the maximum antenna height step size also shall be less than or equal to 5 cm.

When using a spectrum analyzer with tracking generator, the swept frequency method measurement procedure consists of the following steps; a similar procedure shall be used for other types of instrumentation.

The order in which the site measurement and the direct measurement are performed, i.e., steps D.5 d) and D.5 e), is at the discretion of the user.

a) With the transmit antenna and receive antenna connected, adjust the output level of the tracking generator until responses are displayed at a minimum of 6 dB above the system and spectrum analyzer noise floor. Disconnect the antennas (leaving the impedance matching attenuators on the cables, if used per NOTE 1 of D.2.3), then connect the two cables together to verify that the spectrum analyzer is not in an overload condition.

   NOTE 1—Several iterations of adjusting the output level of the tracking generator may be needed to confirm that the preceding response level and overload conditions are satisfied.

b) Connect the antennas, then lower the receive antenna on the mast to the minimum height of the scan range (i.e., 1 m), as indicated in Table D.5 or Table D.6, then verify that the center of the antenna is at this height.

c) Set the spectrum analyzer and tracking generator to sweep the desired frequency range. Confirm that the reference level of the spectrum analyzer is adjusted such that a signal up to 60 dB higher can be displayed on the same amplitude scale without overload – see step D.5 a). This condition accommodates the levels to be recorded in step D.5 e).

d) Use the Trace "Max-Hold" function on the analyzer while slowly scanning the receive antenna height over the scan range as indicated in the tables in D.8 for the appropriate site geometry. Store or record the maximum received voltage versus frequency display (in dBμV).

e) Disconnect the cables from the transmit antenna and the receive antenna then connect them directly together with a straight-through adapter. Sweep the analyzer and its tracking generator over the same frequency range using the same tracking generator level as in the previous step, then store or record the resulting voltage versus frequency display.

[32] Concerning software control of instrumentation and calculations in automated measurements, see, e.g., Clause 8 on measurement integrity in ANSI C63.22-2004.

f) At each frequency, subtract the voltage recorded in step D.5 d) from the voltage recorded in step D.5 e). Also subtract the antenna factors for the transmit antenna and the receive antenna, AF_T and AF_R (in dB/m), respectively. For frequencies not stated in the ANSI C63.5 antenna calibration report, antenna factors shall be obtained by using simple linear interpolation between adjacent discrete antenna factor values. Also subtract the *GSCF* values per Equation (D.2) (see D.2.1). The result is the measured NSA over the range of frequencies used, which shall be plotted and reported. This plot shall also include the theoretical NSA for an ideal site, together with corresponding lower-bound and upper-bound curves, per the site acceptability criterion of 5.4.4.2 of ANSI C63.4-2014, and also report separately in tabular format all measurement results that are within 1 dB of the site acceptability criterion (i.e., as in Table D.10 or similar).

g) If the frequency range of 30 MHz to 1000 MHz was split into smaller ranges due to the antennas used, repeat steps D.5 a) to D.5 f) for all frequency ranges. For each frequency range, report the results plot, including the theoretical NSA tolerance curves per D.5 f), and also report separately in tabular format all measurement results that are within 1 dB of the site acceptability criterion in 5.4.4.2 of ANSI C63.4-2014. Table D.10 contains the recommended worksheet for this tabular-format reporting. The entries in Table D.10 are used for solving Equation (D.2). Descriptions of the entries for each column are given in Table D.11, and Table D.12 gives an example of the use of the worksheet.

NOTE 2—Notwithstanding that the example of Table D.12 considers the discrete frequency method, that example is also representative of use of the Table D.10 worksheet for the swept frequency method.

D.6 Site attenuation deviations

ANSI C63.7 contains descriptions of possible causes for NSA deviations from the theoretical site attenuation of more than the ± 4 dB criterion. Each of the causes described therein should be checked in turn until the excess deviation is reduced to be within the 4 dB site acceptability criterion of 5.4.4.2 of ANSI C63.4-2014.

D.7 Theoretical NSA for an ideal site

The theoretical NSA values listed in the tables of D.8 were calculated using the equations in this subclause. These equations shall be used for calculating the theoretical NSA for an ideal site when the geometries listed in the tables of D.8 do not correspond to the test volume to be validated (e.g., when the height of the test volume to be validated is not listed in the tables of D.8, or if values of greater precision are desired).

The theoretical site attenuation for a perfectly conducting ground plane of infinite extent is given by Equation (D.4) (German [B17]):

$$A_{\mathrm{N\_ideal}} = 48.92 - 20\log_{10}\left(f_{\mathrm{M}}\right) - E_{\mathrm{D}}^{\mathrm{MAX}} \tag{D.4}$$

where

$A_{\mathrm{N\_ideal}}$	is the theoretical site attenuation for an ideal site (dB)
f_{M}	is the frequency (MHz)
$E_{\mathrm{D}}^{\mathrm{MAX}}$	is the maximum electric field strength (dBμV/m) from a half-wave (tuned) dipole at height h_1 radiating one picowatt as seen by a receiving antenna whose height h_2 is scanned over a specified range

The values for $E_{\mathrm{D}}^{\mathrm{MAX}}$ depend on the polarization of the two antennas, and they are equal to the maximum values of E_{DH} and E_{DV}, respectively, given by Equation (D.5) and Equation (D.6) (German [B17]), over the receive antenna height scan range (e.g., 1 m to 4 m, for the case of broadband antennas):

$$E_{\mathrm{DH}} = \frac{\sqrt{49.2}\sqrt{d_1^2 + d_2^2 - 2d_1 d_2 \cos\left[\beta\left(d_2 - d_1\right)\right]}}{d_1 d_2} \tag{D.5}$$

$$E_{\mathrm{DV}} = \frac{R^2 \sqrt{49.2} \sqrt{d_1^6 + d_2^6 + 2 d_1^3 d_2^3 \cos[\beta(d_2 - d_1)]}}{d_1^3 d_2^3} \tag{D.6}$$

where

$$d_1 = \sqrt{R^2 + (h_1 - h_2)^2}$$

$$d_2 = \sqrt{R^2 + (h_1 + h_2)^2}$$

R is the measurement distance (m)
h_1 is the transmit antenna height above the ground plane (m)
h_2 is the receive antenna height above the ground plane (m), scanned through a range (e.g., 1 m to 4 m)
d_1 is the path length (m) of the geometrical-optics direct ray from the transmit antenna to the receive antenna
d_2 is the path length (m) of the geometrical-optics reflected ray from the transmit antenna to the ground plane, then from the ground plane to the receive antenna
λ is the wavelength (m)
β is the wave number (m^{-1}), given by $\beta = 2\pi/\lambda$

NOTE—The receive antenna height h_2 is scanned through a range (e.g., 1 m to 4 m), with Equation (D.5) and Equation (D.6) re-calculated across the entire range of h_2 values to determine $E_{\mathrm{DH}}^{\mathrm{MAX}}$ and $E_{\mathrm{DV}}^{\mathrm{MAX}}$.

D.8 Tables and figures for Annex D

The existing Table D.1 in D.7 of ANSI C63.4-2014, and its caption and footnote a, are changed by dividing into separate tables for each antenna polarization and for the discrete frequency method and the swept frequency method. Replace the existing Table D.1 with the following tables and renumber as Table D.3 through Table D.6.

In the new Table D.3, the four columns (1) to (4) of the former Table D.1 are repeated as columns (1), (2), (7), and (10), respectively, columns (3) to (6), (8), (9), and (11) are inserted, and rows for additional frequencies per the increments specified in D.4 (discrete frequency method) are inserted.

In the new Table D.4, the seven columns (1) and (5) to (10) of the former Table D.1 are repeated as columns (1) to (3), (7), (8), (10), and (11), respectively, columns (4) to (6) and (9) are inserted, and rows for additional frequencies per the increments specified in D.4 (discrete frequency method) are inserted.

The new Table D.5 and Table D.6 repeat all columns as in the new Table D.3 and Table D.4, but rows for frequencies are inserted per the increments specified in D.5 (swept frequency method).

Table D.3—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.4 (discrete frequency method); h_2 = 1 m to 4 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	3 1	3 2	5 1	5 2	5 2.5	10 1	10 2	10 3	30 1	30 2
f_M (MHz)	A_N (dB)									
30	15.8	11.0	20.7	15.6	14.3	29.8	24.1	21.3	47.7	41.7
35	13.4	8.8	18.2	13.3	12.2	27.1	21.6	18.9	45.0	39.1
40	11.3	7.0	16.0	11.4	10.5	24.9	19.4	16.9	42.7	36.8
45	9.4	5.5	14.1	9.8	9.1	22.9	17.5	15.2	40.7	34.7
50	7.8	4.2	12.4	8.5	7.9	21.1	15.9	13.7	38.8	32.9
55	6.3	3.1	10.9	7.3	6.9	19.5	14.4	12.5	37.2	31.3
60	5.0	2.2	9.5	6.3	6.0	18.0	13.1	11.5	35.7	29.8
65	3.8	1.3	8.3	5.4	5.2	16.7	12.0	10.6	34.3	28.4
70	2.8	0.6	7.2	4.6	4.4	15.5	10.9	9.9	33.0	27.2
75	1.8	−0.1	6.2	3.9	3.8	14.3	10.0	9.2	31.8	26.0
80	0.9	−0.7	5.3	3.2	3.2	13.3	9.2	8.6	30.7	24.9
85	0.1	−1.3	4.5	2.6	2.6	12.3	8.4	8.1	29.7	23.9
90	−0.7	−1.8	3.7	2.0	2.1	11.4	7.8	7.5	28.7	23.0
95	−1.4	−2.3	3.0	1.5	1.6	10.5	7.2	7.0	27.7	22.1
100	−2.0	−2.8	2.3	1.0	1.1	9.7	6.7	6.6	26.9	21.2
105	−2.7	−3.2	1.7	0.5	0.7	9.0	6.2	6.1	26.0	20.4
110	−3.2	−3.6	1.1	0.1	0.2	8.3	5.8	5.7	25.2	19.7
115	−3.7	−4.0	0.6	−0.3	−0.2	7.6	5.4	5.3	24.5	18.9
120	−4.2	−4.4	0.1	−0.7	−0.5	7.0	5.0	4.9	23.8	18.2
125	−4.7	−4.8	−0.4	−1.1	−0.9	6.4	4.6	4.5	23.1	17.6
130	−5.1	−5.1	−0.8	−1.5	−1.3	5.8	4.2	4.2	22.4	17.0
135	−5.6	−5.4	−1.2	−1.8	−1.6	5.3	3.8	3.9	21.7	16.4
140	−6.0	−5.8	−1.7	−2.1	−1.9	4.8	3.5	3.5	21.1	15.8
145	−6.3	−6.0	−2.0	−2.4	−2.2	4.3	3.2	3.2	20.5	15.3
150	−6.7	−6.3	−2.4	−2.8	−2.5	3.9	2.9	2.9	20.0	14.7
155	−7.0	−6.5	−2.7	−3.1	−2.8	3.4	2.6	2.6	19.4	14.2
160	−7.4	−6.7	−3.1	−3.3	−3.1	3.0	2.3	2.4	18.9	13.8
165	−7.7	−6.8	−3.4	−3.6	−3.4	2.7	2.0	2.1	18.4	13.3
170	−8.0	−6.9	−3.7	−3.9	−3.6	2.3	1.7	1.8	17.9	12.9
175	−8.3	−7.0	−4.0	−4.1	−3.9	2.0	1.5	1.6	17.4	12.4
180	−8.5	−7.2	−4.3	−4.4	−4.1	1.7	1.2	1.3	16.9	12.0
185	−8.8	−7.5	−4.6	−4.6	−4.3	1.4	1.0	1.1	16.5	11.6
190	−9.1	−7.8	−4.8	−4.9	−4.4	1.1	0.7	0.8	16.0	11.3
195	−9.3	−8.1	−5.1	−5.1	−4.6	0.8	0.5	0.6	15.6	10.9
200	−9.6	−8.4	−5.3	−5.3	−4.7	0.6	0.3	0.4	15.2	10.6
225	−10.7	−9.6	−6.5	−6.3	−5.8	−0.6	−0.8	−0.7	13.2	9.0
250	−11.7	−10.6	−7.5	−6.7	−6.7	−1.6	−1.7	−1.6	11.6	7.8
275	−12.4	−11.5	−8.4	−7.7	−7.6	−2.5	−2.6	−2.4	10.0	6.8
300	−12.8	−12.3	−9.2	−8.5	−8.4	−3.3	−3.3	−3.0	8.7	6.1
300	−12.8	−12.3	−9.2	−8.5	−8.4	−3.3	−3.3	−3.0	8.7	6.1
325	−12.9	−13.0	−9.9	−9.3	−9.2	−4.0	−4.0	−3.7	7.5	5.4
350	−13.1	−13.7	−10.6	−10.0	−9.8	−4.7	−4.7	−4.4	6.4	4.7
375	−14.0	−14.3	−11.2	−10.6	−10.4	−5.3	−5.3	−5.0	5.4	4.1
400	−14.8	−14.9	−11.8	−11.2	−11.0	−5.9	−5.8	−5.6	4.5	3.5

Table D.3—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.4 (discrete frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m **h_1, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
f_M (MHz)	**A_N (dB)**									
425	−15.5	−15.4	−12.2	−11.8	−11.6	−6.4	−6.3	−6.1	3.7	3.0
450	−16.1	−15.8	−12.5	−12.3	−12.1	−6.9	−6.7	−6.6	3.0	2.5
475	−16.7	−16.3	−12.7	−12.8	−12.5	−7.4	−7.2	−7.1	2.4	2.0
500	−17.3	−16.7	−13.0	−13.3	−13.0	−7.9	−7.6	−7.6	1.8	1.6
525	−17.8	−17.2	−13.5	−13.7	−13.3	−8.3	−8.1	−8.0	1.3	1.2
550	−18.2	−17.6	−14.0	−14.1	−13.7	−8.7	−8.5	−8.4	0.8	0.7
575	−18.7	−18.0	−14.4	−14.5	−14.1	−9.1	−8.9	−8.8	0.4	0.4
600	−19.1	−18.4	−14.9	−14.9	−14.5	−9.5	−9.3	−9.2	0.0	0.0
625	−19.5	−18.7	−15.3	−15.2	−14.9	−9.8	−9.6	−9.5	−0.3	−0.4
650	−19.9	−19.1	−15.6	−15.4	−15.2	−10.2	−10.0	−9.9	−0.7	−0.7
675	−20.2	−19.4	−16.0	−15.8	−15.6	−10.5	−10.3	−10.2	−1.0	−1.0
700	−20.6	−19.7	−16.4	−16.1	−15.9	−10.8	−10.7	−10.5	−1.3	−1.4
725	−20.9	−20.0	−16.7	−16.4	−16.2	−11.1	−11.0	−10.8	−1.6	−1.7
750	−21.2	−20.3	−17.0	−16.7	−16.5	−11.4	−11.3	−11.1	−1.9	−2.0
775	−21.3	−20.6	−17.3	−17.0	−16.8	−11.7	−11.6	−11.4	−2.2	−2.2
800	−21.3	−20.9	−17.6	−17.3	−17.1	−12.0	−11.8	−11.6	−2.5	−2.5
825	−21.6	−21.1	−17.9	−17.6	−17.3	−12.2	−12.1	−11.9	−2.8	−2.8
850	−21.9	−21.4	−18.2	−17.9	−17.6	−12.4	−12.4	−12.2	−3.0	−3.0
875	−22.2	−21.7	−18.5	−18.1	−17.8	−12.5	−12.6	−12.4	−3.3	−3.3
900	−22.5	−21.9	−18.7	−18.4	−18.0	−12.8	−12.9	−12.7	−3.5	−3.5
925	−22.8	−22.2	−19.0	−18.6	−18.3	−13.0	−13.1	−12.9	−3.8	−3.8
950	−23.0	−22.4	−19.2	−18.9	−18.5	−13.3	−13.4	−13.1	−4.0	−4.0
975	−23.3	−22.6	−19.4	−19.1	−18.8	−13.5	−13.6	−13.4	−4.2	−4.2
1000	−23.5	−22.8	−19.7	−19.3	−19.0	−13.8	−13.8	−13.6	−4.5	−4.5

[a] For alternative test sites, this data applies for antennas that have 25 cm or more clearance to the covering or absorbers on walls or ceiling.

[b] For geometries other than those listed, the theoretical NSA values for an ideal site shall be calculated as per D.7.

[c] *GSCF* values obtained per ANSI C63.5 shall be inserted in Equation (D.2) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Table D.4—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.4 (discrete frequency method); h_2 = 1 m to 4 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	**3 1**	**3 1.5**	**5 1**	**5 1.5**	**5 2**	**10 1**	**10 1.5**	**10 2.5**	**30 1**	**30 1.5**
f_M (MHz)	**A_N (dB)**									
30	8.2	9.3	11.4	12.0	12.7	16.7	16.9	17.4	26.0	26.0
35	6.9	8.0	10.1	10.7	11.5	15.4	15.6	16.1	24.7	24.7
40	5.8	7.0	8.9	9.6	10.4	14.2	14.4	15.0	23.5	23.5
45	4.9	6.1	7.9	8.6	9.5	13.2	13.4	14.0	22.5	22.5
50	4.0	5.4	7.1	7.8	8.7	12.3	12.5	13.2	21.6	21.6
55	3.3	4.7	6.3	7.0	8.0	11.5	11.7	12.4	20.7	20.8
60	2.6	4.1	5.6	6.3	7.4	10.7	11.0	11.7	20.0	20.0
65	2.0	3.6	4.9	5.7	6.9	10.0	10.3	11.1	19.3	19.3
70	1.5	3.2	4.3	5.2	6.4	9.4	9.7	10.5	18.7	18.7
75	1.0	2.9	3.8	4.7	6.0	8.8	9.1	10.0	18.1	18.1
80	0.6	2.6	3.3	4.3	5.6	8.3	8.6	9.5	17.5	17.5
85	0.2	2.3	2.8	3.9	5.3	7.8	8.1	9.1	17.0	17.0
90	−0.1	2.1	2.4	3.5	5.1	7.3	7.6	8.7	16.5	16.5
95	−0.4	2.0	2.0	3.2	4.9	6.8	7.2	8.3	16.0	16.1
100	−0.7	1.9	1.6	2.9	4.7	6.4	6.8	8.0	15.6	15.6
105	−0.9	1.8	1.2	2.7	4.6	6.0	6.4	7.7	15.1	15.2
110	−1.1	1.8	0.9	2.5	4.5	5.6	6.1	7.4	14.7	14.8
115	−1.3	1.9	0.6	2.3	4.1	5.3	5.7	7.2	14.4	14.4
120	−1.5	1.3	0.3	2.1	3.4	4.9	5.4	7.0	14.0	14.0
125	−1.6	0.5	0.1	2.0	2.7	4.6	5.1	6.8	13.6	13.7
130	−1.7	−0.2	−0.2	1.9	2.1	4.3	4.8	6.6	13.3	13.4
135	−1.7	−0.9	−0.4	1.8	1.5	4.0	4.5	6.4	13.0	13.0
140	−1.8	−1.5	−0.6	1.7	1.0	3.7	4.3	6.2	12.7	12.7
145	−1.8	−2.1	−0.8	1.7	0.5	3.4	4.1	5.5	12.4	12.4
150	−1.8	−2.7	−1.0	1.7	0.1	3.1	3.8	5.0	12.1	12.1
155	−1.8	−3.2	−1.1	1.5	−0.4	2.9	3.6	4.5	11.8	11.9
160	−1.7	−3.7	−1.3	1.0	−0.7	2.6	3.4	4.1	11.5	11.6
165	−1.6	−4.1	−1.4	0.4	−1.1	2.4	3.2	3.7	11.3	11.3
170	−1.5	−4.5	−1.6	−0.1	−1.5	2.2	3.0	3.4	11.0	11.1
175	−1.4	−4.9	−1.7	−0.5	−1.8	2.0	2.9	3.1	10.8	10.8
180	−1.3	−5.3	−1.8	−1.0	−2.2	1.7	2.7	2.8	10.5	10.6
185	−1.9	−5.7	−1.8	−1.4	−2.5	1.5	2.5	2.5	10.3	10.4
190	−2.5	−6.0	−1.9	−1.8	−2.8	1.3	2.4	2.2	10.0	10.2
195	−3.1	−6.4	−2.0	−2.2	−3.1	1.2	2.3	1.9	9.8	9.9
200	−3.6	−6.7	−2.0	−2.6	−3.3	1.0	2.1	1.6	9.6	9.7
225	−5.9	−8.0	−2.1	−4.1	−4.6	0.2	1.6	0.4	8.6	8.8
250	−7.7	−9.1	−3.2	−5.5	−5.6	−0.5	0.3	−0.6	7.7	7.9
275	−9.2	−10.1	−4.8	−6.5	−6.5	−1.1	−0.9	−1.6	6.9	7.1
300	−10.5	−10.9	−6.2	−7.5	−7.3	−1.5	−1.9	−2.4	6.2	6.5
325	−11.5	−11.7	−7.3	−8.4	−8.1	−1.9	−2.8	−3.2	5.5	5.8
350	−12.5	−12.3	−8.3	−9.1	−8.8	−2.1	−3.6	−3.8	4.9	5.3
375	−13.3	−12.7	−9.2	−9.8	−9.4	−3.3	−4.4	−4.5	4.4	4.8
400	−14.0	−12.6	−10.0	−10.5	−10.0	−4.1	−5.0	−5.1	3.9	4.3

Table D.4—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.4 (discrete frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	3 1	3 1.5	5 1	5 1.5	5 2	10 1	10 1.5	10 2.5	30 1	30 1.5
f_M (MHz)	A_N (dB)									
425	−14.7	−13.3	−10.7	−11.0	−10.5	−4.9	−5.6	−5.6	3.4	3.9
450	−15.3	−14.0	−11.4	−11.6	−10.6	−5.5	−6.2	−6.1	2.9	3.5
475	−15.9	−14.6	−12.0	−12.1	−11.1	−6.2	−6.7	−6.6	2.5	3.1
500	−16.4	−15.1	−12.5	−12.6	−11.6	−6.7	−7.2	−7.1	2.1	2.8
525	−16.7	−15.6	−13.0	−13.0	−12.1	−7.3	−7.7	−7.5	1.7	2.5
550	−16.7	−16.1	−13.5	−13.4	−12.5	−7.8	−8.2	−7.9	1.4	2.3
575	−16.5	−16.5	−14.0	−13.5	−13.0	−8.2	−8.6	−8.3	1.1	2.0
600	−16.3	−16.9	−14.4	−13.5	−13.4	−8.7	−9.0	−8.7	0.8	1.8
625	−16.9	−17.3	−14.8	−13.9	−13.8	−9.1	−9.4	−9.1	0.5	1.2
650	−17.5	−17.7	−15.2	−14.4	−14.1	−9.5	−9.7	−9.3	0.2	0.4
675	−18.0	−18.0	−15.6	−14.8	−14.5	−9.9	−10.1	−9.5	0.0	−0.3
700	−18.4	−18.4	−15.9	−15.1	−14.8	−10.2	−10.4	−9.9	−0.3	−0.9
725	−18.9	−18.4	−16.3	−15.5	−15.1	−10.6	−10.7	−10.2	−0.5	−1.4
750	−19.3	−18.7	−16.6	−15.8	−15.4	−10.9	−11.0	−10.5	−0.7	−1.7
775	−19.7	−19.0	−16.9	−16.2	−15.7	−11.2	−11.3	−10.8	−0.9	−2.0
800	−20.0	−19.3	−17.2	−16.5	−16.0	−11.5	−11.6	−11.1	−1.1	−2.3
825	−20.4	−19.6	−17.3	−16.8	−16.3	−11.8	−11.9	−11.4	−1.3	−2.6
850	−20.7	−19.9	−17.4	−17.1	−16.4	−12.1	−12.2	−11.6	−1.4	−2.9
875	−21.0	−20.2	−17.3	−17.3	−16.6	−12.4	−12.4	−11.9	−1.6	−3.1
900	−21.3	−20.5	−17.4	−17.6	−16.9	−12.6	−12.7	−12.1	−1.7	−3.4
925	−21.6	−20.7	−17.7	−17.9	−17.1	−12.9	−12.9	−12.4	−2.0	−3.6
950	−21.9	−21.0	−18.0	−18.1	−17.4	−13.1	−13.2	−12.6	−2.6	−3.9
975	−22.2	−21.2	−18.2	−18.4	−17.6	−13.4	−13.4	−12.9	−3.1	−4.1
1000	−22.4	−21.4	−18.5	−18.6	−17.9	−13.6	−13.6	−13.1	−3.6	−4.3

[a] This data applies for antennas with 25 cm or more clearance to the ground plane when the center of the antenna is 1 m above the ground plane, and antennas with 25 cm or more clearance to the covering or absorbers on walls or ceiling for alternative test sites.

[b] For geometries other than those listed, the theoretical NSA values for an ideal site shall be calculated as per D.7.

[c] *GSCF* values obtained per ANSI C63.5 shall be inserted in Equation (D.2) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
***R*, m** ***h*₁, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
f_M (MHz)	**A_N (dB)**									
30	15.8	11.0	20.7	15.6	14.3	29.8	24.1	21.3	47.7	41.7
32	14.8	10.0	19.7	14.6	13.4	28.7	23.1	20.3	46.6	40.6
34	13.9	9.2	18.7	13.7	12.6	27.6	22.1	19.3	45.5	39.5
36	13.0	8.4	17.7	12.9	11.8	26.7	21.1	18.4	44.5	38.6
38	12.1	7.7	16.8	12.1	11.1	25.7	20.3	17.6	43.6	37.6
40	11.3	7.0	16.0	11.4	10.5	24.9	19.4	16.9	42.7	36.7
42	10.5	6.4	15.2	10.7	9.9	24.0	18.6	16.1	41.8	35.9
44	9.8	5.8	14.5	10.1	9.3	23.2	17.9	15.5	41.0	35.1
46	9.1	5.2	13.7	9.5	8.8	22.5	17.2	14.8	40.3	34.3
48	8.4	4.7	13.1	9.0	8.3	21.8	16.5	14.3	39.5	33.6
50	7.8	4.2	12.4	8.5	7.9	21.1	15.9	13.7	38.8	32.9
52	7.2	3.8	11.8	8.0	7.5	20.4	15.3	13.2	38.1	32.2
54	6.6	3.4	11.2	7.5	7.1	19.8	14.7	12.7	37.5	31.6
56	6.1	2.9	10.6	7.1	6.7	19.2	14.2	12.3	36.9	31.0
58	5.5	2.6	10.1	6.7	6.3	18.6	13.6	11.8	36.3	30.4
60	5.0	2.2	9.5	6.3	6.0	18.0	13.1	11.5	35.7	29.8
62	4.5	1.8	9.0	5.9	5.6	17.5	12.6	11.1	35.1	29.2
64	4.1	1.5	8.6	5.6	5.3	17.0	12.2	10.8	34.6	28.7
66	3.6	1.2	8.1	5.2	5.0	16.4	11.7	10.5	34.0	28.2
68	3.2	0.9	7.6	4.9	4.7	15.9	11.3	10.2	33.5	27.7
70	2.8	0.6	7.2	4.6	4.4	15.5	10.9	9.9	33.0	27.2
72	2.4	0.3	6.8	4.3	4.2	15.0	10.5	9.6	32.5	26.7
74	2.0	0.1	6.4	4.0	3.9	14.6	10.2	9.4	32.0	26.2
76	1.6	−0.2	6.0	3.7	3.6	14.1	9.8	9.1	31.6	25.8
78	1.2	−0.5	5.7	3.5	3.4	13.7	9.5	8.9	31.1	25.4
80	0.9	−0.7	5.3	3.2	3.2	13.3	9.2	8.6	30.7	24.9
82	0.5	−0.9	5.0	2.9	2.9	12.9	8.9	8.4	30.3	24.5
84	0.2	−1.2	4.6	2.7	2.7	12.5	8.6	8.2	29.9	24.1
86	−0.1	−1.4	4.3	2.5	2.5	12.1	8.3	7.9	29.5	23.7
88	−0.4	−1.6	4.0	2.2	2.3	11.8	8.0	7.7	29.1	23.3
90	−0.7	−1.8	3.7	2.0	2.1	11.4	7.8	7.5	28.7	23.0
92	−1.0	−2.0	3.4	1.8	1.9	11.0	7.5	7.3	28.3	22.6
94	−1.3	−2.2	3.1	1.6	1.7	10.7	7.3	7.1	27.9	22.2
96	−1.5	−2.4	2.9	1.4	1.5	10.4	7.1	6.9	27.6	21.9
98	−1.8	−2.6	2.6	1.2	1.3	10.1	6.9	6.7	27.2	21.5
100	−2.0	−2.8	2.3	1.0	1.1	9.7	6.7	6.6	26.9	21.2
102	−2.3	−2.9	2.1	0.8	0.9	9.4	6.5	6.4	26.5	20.9
104	−2.5	−3.1	1.8	0.6	0.7	9.1	6.3	6.2	26.2	20.6
106	−2.8	−3.3	1.6	0.4	0.6	8.8	6.1	6.0	25.9	20.3
108	−3.0	−3.5	1.4	0.3	0.4	8.6	6.0	5.9	25.6	20.0
110	−3.2	−3.6	1.1	0.1	0.2	8.3	5.8	5.7	25.2	19.7
112	−3.4	−3.8	0.9	−0.1	0.1	8.0	5.6	5.5	24.9	19.4
114	−3.6	−3.9	0.7	−0.2	−0.1	7.7	5.4	5.4	24.6	19.1
116	−3.8	−4.1	0.5	−0.4	−0.2	7.5	5.3	5.2	24.3	18.8

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
***R*, m** ***h*₁, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
f_M (MHz)	**A_N (dB)**									
118	−4.0	−4.3	0.3	−0.6	−0.4	7.2	5.1	5.1	24.0	18.5
120	−4.2	−4.4	0.1	−0.7	−0.5	7.0	4.9	4.9	23.8	18.2
122	−4.4	−4.5	−0.1	−0.9	−0.7	6.7	4.8	4.8	23.5	18.0
124	−4.6	−4.7	−0.3	−1.0	−0.8	6.5	4.6	4.6	23.2	17.7
126	−4.8	−4.8	−0.5	−1.2	−1.0	6.3	4.5	4.5	22.9	17.5
128	−5.0	−5.0	−0.6	−1.3	−1.1	6.0	4.3	4.3	22.7	17.2
130	−5.1	−5.1	−0.8	−1.5	−1.3	5.8	4.2	4.2	22.4	17.0
132	−5.3	−5.2	−1.0	−1.6	−1.4	5.6	4.1	4.1	22.1	16.7
134	−5.5	−5.4	−1.2	−1.7	−1.5	5.4	3.9	3.9	21.9	16.5
136	−5.6	−5.5	−1.3	−1.9	−1.7	5.2	3.8	3.8	21.6	16.3
138	−5.8	−5.6	−1.5	−2.0	−1.8	5.0	3.6	3.7	21.4	16.0
140	−6.0	−5.8	−1.6	−2.1	−1.9	4.8	3.5	3.5	21.1	15.8
142	−6.1	−5.9	−1.8	−2.3	−2.0	4.6	3.4	3.4	20.9	15.6
144	−6.3	−6.0	−2.0	−2.4	−2.2	4.4	3.2	3.3	20.7	15.4
146	−6.4	−6.1	−2.1	−2.5	−2.3	4.2	3.1	3.2	20.4	15.2
148	−6.6	−6.2	−2.3	−2.6	−2.4	4.0	3.0	3.0	20.2	14.9
150	−6.7	−6.3	−2.4	−2.8	−2.5	3.9	2.9	2.9	20.0	14.7
152	−6.8	−6.4	−2.5	−2.9	−2.6	3.7	2.7	2.8	19.7	14.5
154	−7.0	−6.5	−2.7	−3.0	−2.8	3.5	2.6	2.7	19.5	14.3
156	−7.1	−6.5	−2.8	−3.1	−2.9	3.4	2.5	2.6	19.3	14.1
158	−7.2	−6.6	−2.9	−3.2	−3.0	3.2	2.4	2.5	19.1	14.0
160	−7.4	−6.7	−3.1	−3.3	−3.1	3.0	2.3	2.3	18.9	13.8
162	−7.5	−6.7	−3.2	−3.4	−3.2	2.9	2.2	2.2	18.7	13.6
164	−7.6	−6.8	−3.3	−3.6	−3.3	2.7	2.1	2.1	18.5	13.4
166	−7.7	−6.8	−3.5	−3.7	−3.4	2.6	1.9	2.0	18.3	13.2
168	−7.9	−6.9	−3.6	−3.8	−3.5	2.5	1.8	1.9	18.1	13.0
170	−8.0	−6.9	−3.7	−3.9	−3.6	2.3	1.7	1.8	17.9	12.9
172	−8.1	−6.9	−3.8	−4.0	−3.7	2.2	1.6	1.7	17.7	12.7
174	−8.2	−7.0	−3.9	−4.1	−3.8	2.0	1.5	1.6	17.5	12.5
176	−8.3	−7.0	−4.1	−4.2	−3.9	1.9	1.4	1.5	17.3	12.4
178	−8.4	−7.1	−4.2	−4.3	−4.0	1.8	1.3	1.4	17.1	12.2
180	−8.6	−7.2	−4.3	−4.4	−4.1	1.7	1.2	1.3	16.9	12.0
182	−8.7	−7.3	−4.4	−4.5	−4.2	1.6	1.1	1.2	16.7	11.9
184	−8.8	−7.4	−4.5	−4.6	−4.2	1.4	1.0	1.1	16.5	11.7
186	−8.9	−7.6	−4.6	−4.7	−4.3	1.3	0.9	1.0	16.4	11.6
188	−9.0	−7.7	−4.7	−4.8	−4.4	1.2	0.8	0.9	16.2	11.4
190	−9.1	−7.8	−4.8	−4.9	−4.4	1.1	0.7	0.8	16.0	11.3
192	−9.2	−7.9	−4.9	−5.0	−4.5	1.0	0.6	0.7	15.8	11.1
194	−9.3	−8.0	−5.0	−5.1	−4.6	0.9	0.5	0.6	15.7	11.0
196	−9.4	−8.2	−5.1	−5.1	−4.6	0.8	0.4	0.6	15.5	10.8
198	−9.5	−8.3	−5.2	−5.2	−4.7	0.7	0.4	0.5	15.3	10.7
200	−9.6	−8.4	−5.3	−5.3	−4.7	0.6	0.3	0.4	15.2	10.6
205	−9.8	−8.6	−5.6	−5.5	−4.8	0.4	0.0	0.2	14.8	10.2
210	−10.1	−8.9	−5.8	−5.8	−5.1	0.1	−0.2	0.0	14.4	9.9

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m **h_1, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
f_M (MHz)	**A_N (dB)**									
215	−10.3	−9.1	−6.0	−5.9	−5.3	−0.1	−0.4	−0.3	14.0	9.6
220	−10.5	−9.4	−6.3	−6.1	−5.5	−0.3	−0.6	−0.5	13.6	9.3
225	−10.7	−9.6	−6.5	−6.3	−5.8	−0.6	−0.8	−0.7	13.2	9.0
230	−10.9	−9.8	−6.7	−6.4	−6.0	−0.8	−1.0	−0.8	12.9	8.8
235	−11.1	−10.0	−6.9	−6.5	−6.2	−1.0	−1.2	−1.0	12.5	8.5
240	−11.3	−10.2	−7.1	−6.6	−6.4	−1.2	−1.4	−1.2	12.2	8.3
245	−11.5	−10.4	−7.3	−6.7	−6.6	−1.4	−1.5	−1.4	11.9	8.0
250	−11.7	−10.6	−7.5	−6.7	−6.8	−1.6	−1.7	−1.6	11.5	7.8
255	−11.8	−10.8	−7.7	−6.9	−6.9	−1.7	−1.9	−1.7	11.2	7.6
260	−12.0	−11.0	−7.8	−7.1	−7.1	−1.9	−2.1	−1.9	10.9	7.4
265	−12.1	−11.2	−8.0	−7.3	−7.3	−2.1	−2.2	−2.1	10.6	7.2
270	−12.3	−11.3	−8.2	−7.5	−7.5	−2.3	−2.4	−2.2	10.3	7.0
275	−12.4	−11.5	−8.4	−7.7	−7.6	−2.5	−2.6	−2.4	10.0	6.8
280	−12.5	−11.7	−8.5	−7.8	−7.8	−2.6	−2.7	−2.5	9.8	6.7
285	−12.6	−11.8	−8.7	−8.0	−8.0	−2.8	−2.9	−2.6	9.5	6.5
290	−12.7	−12.0	−8.9	−8.2	−8.1	−2.9	−3.0	−2.7	9.2	6.4
295	−12.7	−12.2	−9.0	−8.4	−8.3	−3.1	−3.2	−2.8	9.0	6.2
300	−12.8	−12.3	−9.2	−8.5	−8.4	−3.3	−3.3	−3.0	8.7	6.1
305	−12.8	−12.5	−9.3	−8.7	−8.6	−3.4	−3.5	−3.1	8.4	5.9
310	−12.9	−12.6	−9.5	−8.8	−8.7	−3.6	−3.6	−3.3	8.2	5.8
315	−12.9	−12.7	−9.6	−9.0	−8.9	−3.7	−3.8	−3.4	8.0	5.6
320	−12.9	−12.9	−9.8	−9.1	−9.0	−3.9	−3.9	−3.6	7.7	5.5
325	−12.9	−13.0	−9.9	−9.3	−9.2	−4.0	−4.0	−3.7	7.5	5.4
330	−12.9	−13.2	−10.0	−9.4	−9.3	−4.1	−4.2	−3.8	7.3	5.2
335	−12.8	−13.3	−10.2	−9.6	−9.4	−4.3	−4.3	−4.0	7.0	5.1
340	−12.8	−13.4	−10.3	−9.7	−9.6	−4.4	−4.4	−4.1	6.8	5.0
345	−12.9	−13.6	−10.4	−9.9	−9.7	−4.5	−4.6	−4.2	6.6	4.8
350	−13.1	−13.7	−10.6	−10.0	−9.8	−4.7	−4.7	−4.4	6.4	4.7
355	−13.3	−13.8	−10.7	−10.1	−10.0	−4.8	−4.8	−4.5	6.2	4.6
360	−13.5	−13.9	−10.8	−10.2	−10.1	−4.9	−4.9	−4.6	6.0	4.5
365	−13.6	−14.1	−11.0	−10.4	−10.2	−5.0	−5.1	−4.8	5.8	4.3
370	−13.8	−14.2	−11.1	−10.5	−10.3	−5.2	−5.2	−4.9	5.6	4.2
375	−14.0	−14.3	−11.2	−10.6	−10.4	−5.3	−5.3	−5.0	5.4	4.1
380	−14.2	−14.4	−11.3	−10.7	−10.6	−5.4	−5.4	−5.1	5.2	4.0
385	−14.3	−14.5	−11.4	−10.9	−10.7	−5.5	−5.5	−5.2	5.1	3.9
390	−14.5	−14.7	−11.6	−11.0	−10.8	−5.6	−5.6	−5.3	4.9	3.8
395	−14.6	−14.8	−11.7	−11.1	−10.9	−5.8	−5.7	−5.5	4.7	3.6
400	−14.8	−14.9	−11.8	−11.2	−11.0	−5.9	−5.8	−5.6	4.5	3.5
405	−14.9	−15.0	−11.9	−11.3	−11.1	−6.0	−5.9	−5.7	4.4	3.4
410	−15.1	−15.1	−12.0	−11.4	−11.2	−6.1	−6.0	−5.8	4.2	3.3
415	−15.2	−15.2	−12.0	−11.6	−11.3	−6.2	−6.1	−5.9	4.0	3.2
420	−15.4	−15.3	−12.1	−11.7	−11.5	−6.3	−6.2	−6.0	3.9	3.1
425	−15.5	−15.4	−12.2	−11.8	−11.6	−6.4	−6.3	−6.1	3.7	3.0
430	−15.6	−15.4	−12.3	−11.9	−11.7	−6.5	−6.3	−6.2	3.6	2.9

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	3 1	3 2	5 1	5 2	5 2.5	10 1	10 2	10 3	30 1	30 2
f_M (MHz)	A_N (dB)									
435	−15.8	−15.5	−12.4	−12.0	−11.8	−6.6	−6.4	−6.3	3.4	2.8
440	−15.9	−15.6	−12.4	−12.1	−11.9	−6.7	−6.5	−6.4	3.3	2.7
445	−16.0	−15.7	−12.5	−12.2	−12.0	−6.8	−6.6	−6.5	3.1	2.6
450	−16.1	−15.8	−12.5	−12.3	−12.1	−6.9	−6.7	−6.6	3.0	2.5
455	−16.3	−15.9	−12.6	−12.4	−12.2	−7.0	−6.8	−6.7	2.9	2.4
460	−16.4	−16.0	−12.6	−12.5	−12.3	−7.1	−6.9	−6.8	2.7	2.3
465	−16.5	−16.1	−12.7	−12.6	−12.4	−7.2	−7.0	−6.9	2.6	2.2
470	−16.6	−16.2	−12.7	−12.7	−12.4	−7.3	−7.1	−7.0	2.5	2.1
475	−16.7	−16.3	−12.7	−12.8	−12.5	−7.4	−7.2	−7.1	2.4	2.0
480	−16.8	−16.4	−12.8	−12.9	−12.6	−7.5	−7.3	−7.2	2.2	1.9
485	−16.9	−16.5	−12.8	−13.0	−12.7	−7.6	−7.4	−7.3	2.1	1.8
490	−17.1	−16.6	−12.8	−13.1	−12.8	−7.7	−7.4	−7.4	2.0	1.8
495	−17.2	−16.7	−12.9	−13.2	−12.9	−7.8	−7.5	−7.5	1.9	1.7
500	−17.3	−16.7	−13.0	−13.2	−13.0	−7.9	−7.6	−7.6	1.8	1.6
505	−17.4	−16.8	−13.1	−13.3	−13.1	−8.0	−7.7	−7.6	1.7	1.5
510	−17.5	−16.9	−13.2	−13.4	−13.2	−8.0	−7.8	−7.7	1.6	1.4
515	−17.6	−17.0	−13.3	−13.5	−13.2	−8.1	−7.9	−7.8	1.5	1.3
520	−17.7	−17.1	−13.4	−13.6	−13.3	−8.2	−8.0	−7.9	1.4	1.2
525	−17.8	−17.2	−13.5	−13.7	−13.3	−8.3	−8.1	−8.0	1.3	1.2
530	−17.9	−17.3	−13.6	−13.8	−13.4	−8.4	−8.2	−8.1	1.2	1.1
535	−18.0	−17.4	−13.7	−13.8	−13.5	−8.5	−8.2	−8.2	1.1	1.0
540	−18.1	−17.4	−13.8	−13.9	−13.6	−8.5	−8.3	−8.2	1.0	0.9
545	−18.1	−17.5	−13.9	−14.0	−13.7	−8.6	−8.4	−8.3	0.9	0.8
550	−18.2	−17.6	−14.0	−14.1	−13.7	−8.7	−8.5	−8.4	0.8	0.7
555	−18.3	−17.7	−14.1	−14.2	−13.8	−8.8	−8.6	−8.5	0.7	0.7
560	−18.4	−17.8	−14.2	−14.3	−13.9	−8.9	−8.7	−8.6	0.6	0.6
565	−18.5	−17.8	−14.2	−14.3	−14.0	−8.9	−8.7	−8.6	0.6	0.5
570	−18.6	−17.9	−14.3	−14.4	−14.1	−9.0	−8.8	−8.7	0.5	0.4
575	−18.7	−18.0	−14.4	−14.5	−14.1	−9.1	−8.9	−8.8	0.4	0.4
580	−18.8	−18.1	−14.5	−14.6	−14.2	−9.2	−9.0	−8.9	0.3	0.3
585	−18.9	−18.2	−14.6	−14.6	−14.3	−9.3	−9.1	−8.9	0.3	0.2
590	−18.9	−18.2	−14.7	−14.7	−14.4	−9.3	−9.1	−9.0	0.2	0.1
595	−19.0	−18.3	−14.8	−14.8	−14.4	−9.4	−9.2	−9.1	0.1	0.1
600	−19.1	−18.4	−14.8	−14.9	−14.5	−9.5	−9.3	−9.2	0.0	0.0
605	−19.2	−18.5	−14.9	−14.9	−14.6	−9.6	−9.4	−9.2	0.0	−0.1
610	−19.3	−18.5	−15.0	−15.0	−14.7	−9.6	−9.4	−9.3	−0.1	−0.2
615	−19.3	−18.6	−15.1	−15.1	−14.7	−9.7	−9.5	−9.4	−0.2	−0.2
620	−19.4	−18.7	−15.2	−15.2	−14.8	−9.8	−9.6	−9.5	−0.3	−0.3
625	−19.5	−18.7	−15.3	−15.2	−14.9	−9.8	−9.6	−9.5	−0.3	−0.4
630	−19.6	−18.8	−15.3	−15.2	−15.0	−9.9	−9.7	−9.6	−0.4	−0.4
635	−19.7	−18.9	−15.4	−15.3	−15.0	−10.0	−9.8	−9.7	−0.5	−0.5
640	−19.7	−19.0	−15.5	−15.3	−15.1	−10.0	−9.9	−9.7	−0.5	−0.6
645	−19.8	−19.0	−15.6	−15.4	−15.2	−10.1	−9.9	−9.8	−0.6	−0.6
650	−19.9	−19.1	−15.6	−15.4	−15.2	−10.2	−10.0	−9.9	−0.7	−0.7

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
***R*, m** ***h*₁, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
***f*M (MHz)**	***A*N (dB)**									
655	−19.9	−19.2	−15.7	−15.5	−15.3	−10.3	−10.1	−9.9	−0.7	−0.8
660	−20.0	−19.2	−15.8	−15.6	−15.4	−10.3	−10.1	−10.0	−0.8	−0.8
665	−20.1	−19.3	−15.9	−15.6	−15.4	−10.4	−10.2	−10.1	−0.9	−0.9
670	−20.2	−19.4	−15.9	−15.7	−15.5	−10.5	−10.3	−10.1	−0.9	−1.0
675	−20.2	−19.4	−16.0	−15.8	−15.6	−10.5	−10.3	−10.2	−1.0	−1.0
680	−20.3	−19.5	−16.1	−15.8	−15.6	−10.6	−10.4	−10.3	−1.1	−1.1
685	−20.4	−19.6	−16.1	−15.9	−15.7	−10.6	−10.5	−10.3	−1.1	−1.2
690	−20.4	−19.6	−16.2	−16.0	−15.8	−10.7	−10.5	−10.4	−1.2	−1.2
695	−20.5	−19.7	−16.3	−16.0	−15.8	−10.8	−10.6	−10.5	−1.3	−1.3
700	−20.6	−19.7	−16.4	−16.1	−15.9	−10.8	−10.7	−10.5	−1.3	−1.4
705	−20.6	−19.7	−16.4	−16.2	−16.0	−10.9	−10.7	−10.6	−1.4	−1.4
710	−20.7	−19.8	−16.5	−16.2	−16.0	−11.0	−10.8	−10.6	−1.5	−1.5
715	−20.8	−19.9	−16.6	−16.3	−16.1	−11.0	−10.8	−10.7	−1.5	−1.5
720	−20.8	−19.9	−16.6	−16.4	−16.1	−11.1	−10.9	−10.8	−1.6	−1.6
725	−20.9	−20.0	−16.7	−16.4	−16.2	−11.1	−11.0	−10.8	−1.6	−1.7
730	−21.0	−20.0	−16.8	−16.5	−16.3	−11.2	−11.0	−10.9	−1.7	−1.7
735	−21.0	−20.1	−16.8	−16.5	−16.3	−11.3	−11.1	−10.9	−1.8	−1.8
740	−21.1	−20.2	−16.9	−16.6	−16.4	−11.3	−11.1	−11.0	−1.8	−1.8
745	−21.2	−20.2	−16.9	−16.7	−16.4	−11.4	−11.2	−11.1	−1.9	−1.9
750	−21.2	−20.3	−17.0	−16.7	−16.5	−11.4	−11.3	−11.1	−1.9	−2.0
755	−21.3	−20.3	−17.1	−16.8	−16.6	−11.5	−11.3	−11.2	−2.0	−2.0
760	−21.3	−20.4	−17.1	−16.8	−16.6	−11.6	−11.4	−11.2	−2.1	−2.1
765	−21.3	−20.5	−17.2	−16.9	−16.7	−11.6	−11.4	−11.3	−2.1	−2.1
770	−21.3	−20.5	−17.3	−17.0	−16.7	−11.7	−11.5	−11.3	−2.2	−2.2
775	−21.3	−20.6	−17.3	−17.0	−16.8	−11.7	−11.6	−11.4	−2.2	−2.2
780	−21.3	−20.6	−17.4	−17.1	−16.8	−11.8	−11.6	−11.5	−2.3	−2.3
785	−21.3	−20.7	−17.4	−17.1	−16.9	−11.8	−11.7	−11.5	−2.3	−2.4
790	−21.3	−20.8	−17.5	−17.2	−17.0	−11.9	−11.7	−11.6	−2.4	−2.4
795	−21.3	−20.8	−17.6	−17.3	−17.0	−11.9	−11.8	−11.6	−2.4	−2.5
800	−21.3	−20.9	−17.6	−17.3	−17.1	−12.0	−11.8	−11.7	−2.5	−2.5
805	−21.3	−20.9	−17.7	−17.4	−17.1	−12.0	−11.9	−11.7	−2.6	−2.6
810	−21.4	−21.0	−17.7	−17.4	−17.2	−12.1	−11.9	−11.7	−2.6	−2.6
815	−21.5	−21.0	−17.8	−17.5	−17.2	−12.1	−12.0	−11.8	−2.7	−2.7
820	−21.5	−21.1	−17.8	−17.5	−17.3	−12.1	−12.1	−11.8	−2.7	−2.7
825	−21.6	−21.1	−17.9	−17.6	−17.3	−12.2	−12.1	−11.9	−2.8	−2.8
830	−21.7	−21.2	−18.0	−17.6	−17.4	−12.2	−12.2	−12.0	−2.8	−2.8
835	−21.7	−21.2	−18.0	−17.7	−17.4	−12.3	−12.2	−12.0	−2.9	−2.9
840	−21.8	−21.3	−18.1	−17.8	−17.5	−12.3	−12.3	−12.1	−2.9	−2.9
845	−21.8	−21.4	−18.1	−17.8	−17.5	−12.3	−12.3	−12.1	−3.0	−3.0
850	−21.9	−21.4	−18.2	−17.9	−17.6	−12.4	−12.4	−12.2	−3.0	−3.0
855	−22.0	−21.5	−18.2	−17.9	−17.6	−12.4	−12.4	−12.2	−3.1	−3.1
860	−22.0	−21.5	−18.3	−18.0	−17.7	−12.4	−12.5	−12.3	−3.1	−3.1
865	−22.1	−21.6	−18.3	−18.0	−17.7	−12.5	−12.5	−12.3	−3.2	−3.2
870	−22.1	−21.6	−18.4	−18.1	−17.8	−12.5	−12.6	−12.4	−3.2	−3.2

Table D.5—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, horizontal polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
***R*, m** ***h*₁, m**	**3** **1**	**3** **2**	**5** **1**	**5** **2**	**5** **2.5**	**10** **1**	**10** **2**	**10** **3**	**30** **1**	**30** **2**
f_M (MHz)	**A_N (dB)**									
875	−22.2	−21.7	−18.5	−18.1	−17.8	−12.5	−12.6	−12.4	−3.3	−3.3
880	−22.3	−21.7	−18.5	−18.2	−17.9	−12.6	−12.7	−12.5	−3.3	−3.3
885	−22.3	−21.8	−18.6	−18.2	−17.9	−12.6	−12.7	−12.5	−3.4	−3.4
890	−22.4	−21.8	−18.6	−18.3	−18.0	−12.7	−12.8	−12.6	−3.4	−3.4
895	−22.4	−21.9	−18.7	−18.3	−18.0	−12.7	−12.8	−12.6	−3.5	−3.5
900	−22.5	−21.9	−18.7	−18.4	−18.1	−12.8	−12.9	−12.7	−3.5	−3.5
905	−22.5	−22.0	−18.8	−18.4	−18.1	−12.8	−12.9	−12.7	−3.6	−3.6
910	−22.6	−22.0	−18.8	−18.5	−18.2	−12.9	−13.0	−12.8	−3.6	−3.6
915	−22.7	−22.1	−18.9	−18.5	−18.2	−12.9	−13.0	−12.8	−3.7	−3.7
920	−22.7	−22.1	−18.9	−18.6	−18.2	−13.0	−13.1	−12.9	−3.7	−3.7
925	−22.8	−22.2	−19.0	−18.6	−18.3	−13.0	−13.1	−12.9	−3.8	−3.8
930	−22.8	−22.2	−19.0	−18.7	−18.3	−13.1	−13.2	−13.0	−3.8	−3.8
935	−22.9	−22.3	−19.1	−18.7	−18.4	−13.1	−13.2	−13.0	−3.9	−3.9
940	−22.9	−22.3	−19.1	−18.8	−18.4	−13.2	−13.3	−13.1	−3.9	−3.9
945	−23.0	−22.3	−19.2	−18.8	−18.5	−13.2	−13.3	−13.1	−4.0	−4.0
950	−23.0	−22.4	−19.2	−18.9	−18.5	−13.3	−13.4	−13.1	−4.0	−4.0
955	−23.1	−22.4	−19.3	−18.9	−18.6	−13.3	−13.4	−13.2	−4.1	−4.1
960	−23.1	−22.5	−19.3	−18.9	−18.6	−13.4	−13.4	−13.2	−4.1	−4.1
965	−23.2	−22.5	−19.3	−19.0	−18.7	−13.4	−13.5	−13.3	−4.1	−4.1
970	−23.2	−22.6	−19.4	−19.0	−18.7	−13.5	−13.5	−13.3	−4.2	−4.2
975	−23.3	−22.6	−19.4	−19.1	−18.8	−13.5	−13.6	−13.4	−4.2	−4.2
980	−23.3	−22.6	−19.5	−19.1	−18.8	−13.6	−13.6	−13.4	−4.3	−4.3
985	−23.4	−22.7	−19.5	−19.2	−18.9	−13.6	−13.7	−13.5	−4.3	−4.3
990	−23.4	−22.7	−19.6	−19.2	−18.9	−13.7	−13.7	−13.5	−4.4	−4.4
995	−23.5	−22.7	−19.6	−19.3	−18.9	−13.7	−13.8	−13.6	−4.4	−4.4
1000	−23.5	−22.8	−19.7	−19.3	−19.0	−13.8	−13.8	−13.6	−4.5	−4.5

[a] For alternative test sites, this data applies for antennas that have 25 cm or more clearance to the covering or absorbers on walls or ceiling.
[b] For geometries other than those listed, the theoretical NSA values for an ideal site shall be calculated as per D.7.
[c] *GSCF* values obtained per ANSI C63.5 shall be inserted in Equation (D.2) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	3 1	3 1.5	5 1	5 1.5	5 2	10 1	10 1.5	10 2.5	30 1	30 1.5
f_M (MHz)	A_N (dB)									
30	8.2	9.3	11.4	12.0	12.7	16.7	16.9	17.4	26.0	26.0
32	7.7	8.8	10.8	11.4	12.2	16.1	16.3	16.9	25.4	25.5
34	7.1	8.3	10.3	10.9	11.7	15.6	15.8	16.4	24.9	24.9
36	6.7	7.8	9.8	10.4	11.2	15.1	15.3	15.9	24.4	24.4
38	6.2	7.4	9.4	10.0	10.8	14.7	14.8	15.4	24.0	24.0
40	5.8	7.0	8.9	9.6	10.4	14.2	14.4	15.0	23.5	23.5
42	5.4	6.6	8.5	9.2	10.0	13.8	14.0	14.6	23.1	23.1
44	5.0	6.3	8.1	8.8	9.7	13.4	13.6	14.2	22.7	22.7
46	4.7	5.9	7.8	8.4	9.3	13.0	13.2	13.8	22.3	22.3
48	4.3	5.6	7.4	8.1	9.0	12.6	12.8	13.5	21.9	22.0
50	4.0	5.3	7.1	7.8	8.7	12.3	12.5	13.2	21.6	21.6
52	3.7	5.1	6.7	7.4	8.4	12.0	12.2	12.8	21.2	21.3
54	3.4	4.8	6.4	7.2	8.1	11.6	11.9	12.5	20.9	20.9
56	3.1	4.6	6.1	6.9	7.9	11.3	11.5	12.2	20.6	20.6
58	2.9	4.3	5.8	6.6	7.6	11.0	11.2	12.0	20.3	20.3
60	2.6	4.1	5.6	6.3	7.4	10.7	11.0	11.7	20.0	20.0
62	2.4	3.9	5.3	6.1	7.2	10.5	10.7	11.4	19.7	19.7
64	2.1	3.7	5.0	5.9	7.0	10.2	10.4	11.2	19.4	19.5
66	1.9	3.5	4.8	5.6	6.8	9.9	10.2	11.0	19.2	19.2
68	1.7	3.4	4.5	5.4	6.6	9.7	9.9	10.7	18.9	18.9
70	1.5	3.2	4.3	5.2	6.4	9.4	9.7	10.5	18.7	18.7
72	1.3	3.1	4.1	5.0	6.2	9.2	9.4	10.3	18.4	18.4
74	1.1	2.9	3.9	4.8	6.1	8.9	9.2	10.1	18.2	18.2
76	0.9	2.8	3.7	4.6	5.9	8.7	9.0	9.9	17.9	18.0
78	0.8	2.7	3.5	4.5	5.8	8.5	8.8	9.7	17.7	17.8
80	0.6	2.6	3.3	4.3	5.6	8.3	8.6	9.5	17.5	17.5
82	0.4	2.5	3.1	4.1	5.5	8.1	8.4	9.3	17.3	17.3
84	0.3	2.4	2.9	4.0	5.4	7.9	8.2	9.2	17.1	17.1
86	0.1	2.3	2.7	3.8	5.3	7.7	8.0	9.0	16.9	16.9
88	0.0	2.2	2.5	3.7	5.2	7.5	7.8	8.8	16.7	16.7
90	−0.1	2.1	2.4	3.5	5.1	7.3	7.6	8.7	16.5	16.5
92	−0.3	2.1	2.2	3.4	5.0	7.1	7.5	8.5	16.3	16.3
94	−0.4	2.0	2.0	3.3	4.9	6.9	7.3	8.4	16.1	16.1
96	−0.5	2.0	1.9	3.2	4.9	6.8	7.1	8.3	15.9	16.0
98	−0.6	1.9	1.7	3.0	4.8	6.6	7.0	8.1	15.7	15.8
100	−0.7	1.9	1.6	2.9	4.7	6.4	6.8	8.0	15.6	15.6
102	−0.8	1.9	1.4	2.8	4.7	6.3	6.6	7.9	15.4	15.4
104	−0.9	1.8	1.3	2.7	4.6	6.1	6.5	7.8	15.2	15.3
106	−1.0	1.8	1.2	2.6	4.6	5.9	6.3	7.7	15.1	15.1
108	−1.1	1.8	1.0	2.5	4.6	5.8	6.2	7.5	14.9	15.0
110	−1.1	1.8	0.9	2.5	4.5	5.6	6.1	7.4	14.7	14.8
112	−1.2	1.8	0.8	2.4	4.5	5.5	5.9	7.3	14.6	14.6
114	−1.3	1.9	0.7	2.3	4.2	5.3	5.8	7.2	14.4	14.5
116	−1.4	1.9	0.6	2.2	3.9	5.2	5.7	7.1	14.3	14.3
118	−1.4	1.6	0.4	2.2	3.6	5.1	5.5	7.1	14.1	14.2

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m **h_1, m**	**3** **1**	**3** **1.5**	**5** **1**	**5** **1.5**	**5** **2**	**10** **1**	**10** **1.5**	**10** **2.5**	**30** **1**	**30** **1.5**
f_M (MHz)	**A_N (dB)**									
120	−1.5	1.3	0.3	2.1	3.4	4.9	5.4	7.0	14.0	14.0
122	−1.5	0.9	0.2	2.0	3.1	4.8	5.3	6.9	13.9	13.9
124	−1.6	0.6	0.1	2.0	2.8	4.6	5.2	6.8	13.7	13.8
126	−1.6	0.4	0.0	1.9	2.6	4.5	5.0	6.7	13.6	13.6
128	−1.6	0.1	−0.1	1.9	2.3	4.4	4.9	6.7	13.4	13.5
130	−1.7	−0.2	−0.2	1.9	2.1	4.3	4.8	6.6	13.3	13.4
132	−1.7	−0.5	−0.3	1.8	1.9	4.1	4.7	6.5	13.2	13.2
134	−1.7	−0.8	−0.4	1.8	1.6	4.0	4.6	6.5	13.0	13.1
136	−1.8	−1.0	−0.4	1.8	1.4	3.9	4.5	6.4	12.9	13.0
138	−1.8	−1.3	−0.5	1.7	1.2	3.8	4.4	6.4	12.8	12.9
140	−1.8	−1.5	−0.6	1.7	1.0	3.7	4.3	6.2	12.7	12.7
142	−1.8	−1.8	−0.7	1.7	0.8	3.6	4.2	5.9	12.5	12.6
144	−1.8	−2.0	−0.8	1.7	0.6	3.5	4.1	5.7	12.4	12.5
146	−1.8	−2.2	−0.8	1.7	0.4	3.3	4.0	5.4	12.3	12.4
148	−1.8	−2.4	−0.9	1.7	0.3	3.2	3.9	5.2	12.2	12.3
150	−1.8	−2.7	−1.0	1.7	0.1	3.1	3.8	5.0	12.1	12.1
152	−1.8	−2.9	−1.0	1.7	−0.1	3.0	3.7	4.8	12.0	12.0
154	−1.8	−3.1	−1.1	1.6	−0.3	2.9	3.6	4.6	11.8	11.9
156	−1.7	−3.3	−1.2	1.4	−0.4	2.8	3.6	4.4	11.7	11.8
158	−1.7	−3.5	−1.2	1.2	−0.6	2.7	3.5	4.3	11.6	11.7
160	−1.7	−3.7	−1.3	1.0	−0.8	2.6	3.4	4.1	11.5	11.6
162	−1.7	−3.8	−1.4	0.7	−0.9	2.5	3.3	4.0	11.4	11.5
164	−1.6	−4.0	−1.4	0.5	−1.1	2.4	3.2	3.8	11.3	11.4
166	−1.6	−4.2	−1.5	0.3	−1.2	2.3	3.2	3.7	11.2	11.3
168	−1.5	−4.4	−1.5	0.1	−1.3	2.3	3.1	3.5	11.1	11.2
170	−1.5	−4.5	−1.6	−0.1	−1.5	2.2	3.0	3.4	11.0	11.1
172	−1.4	−4.7	−1.6	−0.3	−1.6	2.1	3.0	3.3	10.9	11.0
174	−1.4	−4.9	−1.6	−0.5	−1.8	2.0	2.9	3.1	10.8	10.9
176	−1.3	−5.0	−1.7	−0.6	−1.9	1.9	2.8	3.0	10.7	10.8
178	−1.3	−5.2	−1.7	−0.8	−2.0	1.8	2.8	2.9	10.6	10.7
180	−1.3	−5.3	−1.8	−1.0	−2.2	1.7	2.7	2.8	10.5	10.6
182	−1.6	−5.5	−1.8	−1.2	−2.3	1.7	2.6	2.6	10.4	10.5
184	−1.8	−5.6	−1.8	−1.3	−2.4	1.6	2.6	2.5	10.3	10.4
186	−2.1	−5.8	−1.9	−1.5	−2.5	1.5	2.5	2.4	10.2	10.3
188	−2.3	−5.9	−1.9	−1.7	−2.6	1.4	2.4	2.3	10.1	10.2
190	−2.5	−6.0	−1.9	−1.8	−2.8	1.3	2.4	2.2	10.0	10.2
192	−2.7	−6.2	−1.9	−2.0	−2.9	1.3	2.3	2.1	10.0	10.1
194	−3.0	−6.3	−2.0	−2.1	−3.0	1.2	2.3	2.0	9.9	10.0
196	−3.2	−6.4	−2.0	−2.3	−3.1	1.1	2.2	1.8	9.8	9.9
198	−3.4	−6.5	−2.0	−2.4	−3.2	1.0	2.2	1.7	9.7	9.8
200	−3.6	−6.7	−2.0	−2.6	−3.3	1.0	2.1	1.6	9.6	9.7
205	−4.1	−7.0	−2.0	−2.9	−3.6	0.8	2.0	1.4	9.4	9.5
210	−4.6	−7.2	−2.1	−3.2	−3.8	0.6	1.9	1.1	9.2	9.3
215	−5.0	−7.5	−2.1	−3.5	−4.1	0.5	1.8	0.9	9.0	9.1
220	−5.5	−7.8	−2.1	−3.9	−4.3	0.3	1.7	0.6	8.8	8.9

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
***R*, m** ***h*₁, m**	**3** **1**	**3** **1.5**	**5** **1**	**5** **1.5**	**5** **2**	**10** **1**	**10** **1.5**	**10** **2.5**	**30** **1**	**30** **1.5**
f_M (MHz)	**A_N (dB)**									
225	−5.9	−8.0	−2.1	−4.1	−4.6	0.2	1.6	0.4	8.6	8.8
230	−6.3	−8.3	−2.0	−4.4	−4.8	0.0	1.5	0.2	8.4	8.6
235	−6.7	−8.5	−2.1	−4.7	−5.0	−0.1	1.3	0.0	8.2	8.4
240	−7.0	−8.7	−2.5	−5.0	−5.2	−0.3	1.0	−0.2	8.1	8.2
245	−7.4	−8.9	−2.8	−5.2	−5.4	−0.4	0.6	−0.4	7.9	8.1
250	−7.7	−9.1	−3.2	−5.4	−5.6	−0.5	0.3	−0.6	7.7	7.9
255	−8.0	−9.3	−3.5	−5.7	−5.8	−0.6	0.0	−0.8	7.6	7.7
260	−8.4	−9.5	−3.9	−5.9	−6.0	−0.7	−0.2	−1.0	7.4	7.6
265	−8.7	−9.7	−4.2	−6.1	−6.2	−0.9	−0.5	−1.2	7.2	7.4
270	−8.9	−9.9	−4.5	−6.3	−6.4	−1.0	−0.7	−1.4	7.1	7.3
275	−9.2	−10.1	−4.8	−6.5	−6.5	−1.1	−0.9	−1.6	6.9	7.1
280	−9.5	−10.3	−5.1	−6.8	−6.7	−1.2	−1.1	−1.7	6.8	7.0
285	−9.8	−10.4	−5.4	−6.9	−6.9	−1.3	−1.3	−1.9	6.6	6.9
290	−10.0	−10.6	−5.6	−7.1	−7.0	−1.3	−1.5	−2.1	6.5	6.7
295	−10.2	−10.8	−5.9	−7.3	−7.2	−1.4	−1.7	−2.2	6.3	6.6
300	−10.5	−10.9	−6.2	−7.5	−7.4	−1.5	−1.9	−2.4	6.2	6.5
305	−10.7	−11.1	−6.4	−7.7	−7.5	−1.6	−2.1	−2.6	6.1	6.3
310	−10.9	−11.2	−6.6	−7.9	−7.7	−1.7	−2.3	−2.7	5.9	6.2
315	−11.1	−11.4	−6.9	−8.0	−7.8	−1.7	−2.5	−2.9	5.8	6.1
320	−11.3	−11.5	−7.1	−8.2	−8.0	−1.8	−2.7	−3.0	5.7	6.0
325	−11.5	−11.7	−7.3	−8.4	−8.1	−1.9	−2.8	−3.2	5.5	5.8
330	−11.7	−11.8	−7.5	−8.5	−8.2	−1.9	−3.0	−3.3	5.4	5.7
335	−11.9	−12.0	−7.7	−8.7	−8.4	−2.0	−3.2	−3.4	5.3	5.6
340	−12.1	−12.1	−7.9	−8.8	−8.5	−2.0	−3.3	−3.6	5.2	5.5
345	−12.3	−12.2	−8.1	−9.0	−8.6	−2.1	−3.5	−3.7	5.0	5.4
350	−12.5	−12.3	−8.3	−9.1	−8.8	−2.1	−3.6	−3.8	4.9	5.3
355	−12.7	−12.5	−8.5	−9.3	−8.9	−2.4	−3.8	−4.0	4.8	5.2
360	−12.8	−12.5	−8.7	−9.4	−9.0	−2.6	−3.9	−4.1	4.7	5.1
365	−13.0	−12.6	−8.9	−9.5	−9.2	−2.9	−4.1	−4.2	4.6	5.0
370	−13.1	−12.7	−9.0	−9.7	−9.3	−3.1	−4.2	−4.4	4.5	4.9
375	−13.3	−12.7	−9.2	−9.8	−9.4	−3.3	−4.4	−4.5	4.4	4.8
380	−13.5	−12.7	−9.4	−9.9	−9.5	−3.5	−4.5	−4.6	4.3	4.7
385	−13.6	−12.7	−9.5	−10.1	−9.6	−3.7	−4.6	−4.7	4.2	4.6
390	−13.8	−12.7	−9.7	−10.2	−9.8	−3.8	−4.8	−4.8	4.1	4.5
395	−13.9	−12.7	−9.8	−10.3	−9.9	−4.0	−4.9	−5.0	3.9	4.4
400	−14.0	−12.6	−10.0	−10.5	−10.0	−4.1	−5.0	−5.1	3.8	4.3
405	−14.2	−12.8	−10.1	−10.6	−10.1	−4.3	−5.2	−5.2	3.7	4.2
410	−14.3	−12.9	−10.3	−10.7	−10.2	−4.4	−5.3	−5.3	3.7	4.1
415	−14.5	−13.1	−10.4	−10.8	−10.3	−4.6	−5.4	−5.4	3.6	4.0
420	−14.6	−13.2	−10.6	−10.9	−10.4	−4.7	−5.5	−5.5	3.5	4.0
425	−14.7	−13.3	−10.7	−11.0	−10.5	−4.9	−5.6	−5.6	3.4	3.9
430	−14.8	−13.5	−10.8	−11.2	−10.5	−5.0	−5.8	−5.7	3.3	3.8
435	−15.0	−13.6	−11.0	−11.3	−10.6	−5.1	−5.9	−5.8	3.2	3.7
440	−15.1	−13.7	−11.1	−11.4	−10.6	−5.3	−6.0	−5.9	3.1	3.6
445	−15.2	−13.9	−11.2	−11.5	−10.6	−5.4	−6.1	−6.0	3.0	3.6

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	**3 1**	**3 1.5**	**5 1**	**5 1.5**	**5 2**	**10 1**	**10 1.5**	**10 2.5**	**30 1**	**30 1.5**
f_M (MHz)	**A_N (dB)**									
450	−15.3	−14.0	−11.4	−11.6	−10.6	−5.5	−6.2	−6.1	2.9	3.5
455	−15.4	−14.1	−11.5	−11.7	−10.7	−5.7	−6.3	−6.2	2.8	3.4
460	−15.6	−14.3	−11.6	−11.8	−10.8	−5.8	−6.4	−6.3	2.7	3.4
465	−15.7	−14.4	−11.7	−11.9	−10.9	−5.9	−6.5	−6.4	2.7	3.3
470	−15.8	−14.5	−11.8	−12.0	−11.0	−6.0	−6.6	−6.5	2.6	3.2
475	−15.9	−14.6	−12.0	−12.1	−11.1	−6.2	−6.7	−6.6	2.5	3.1
480	−16.0	−14.7	−12.1	−12.2	−11.2	−6.3	−6.8	−6.7	2.4	3.1
485	−16.1	−14.8	−12.2	−12.3	−11.3	−6.4	−6.9	−6.8	2.3	3.0
490	−16.2	−14.9	−12.3	−12.4	−11.4	−6.5	−7.0	−6.9	2.3	3.0
495	−16.3	−15.0	−12.4	−12.5	−11.5	−6.6	−7.1	−7.0	2.2	2.9
500	−16.4	−15.1	−12.5	−12.6	−11.6	−6.7	−7.2	−7.1	2.1	2.8
505	−16.5	−15.2	−12.6	−12.7	−11.7	−6.8	−7.3	−7.2	2.0	2.8
510	−16.5	−15.3	−12.7	−12.8	−11.8	−7.0	−7.4	−7.3	2.0	2.7
515	−16.6	−15.4	−12.8	−12.9	−11.9	−7.1	−7.5	−7.3	1.9	2.7
520	−16.6	−15.5	−12.9	−12.9	−12.0	−7.2	−7.6	−7.4	1.8	2.6
525	−16.7	−15.6	−13.0	−13.0	−12.1	−7.3	−7.7	−7.5	1.7	2.5
530	−16.7	−15.7	−13.1	−13.1	−12.2	−7.4	−7.8	−7.6	1.7	2.5
535	−16.7	−15.8	−13.2	−13.2	−12.3	−7.5	−7.9	−7.7	1.6	2.4
540	−16.7	−15.9	−13.3	−13.3	−12.4	−7.6	−8.0	−7.8	1.5	2.4
545	−16.7	−16.0	−13.4	−13.3	−12.5	−7.7	−8.1	−7.9	1.5	2.3
550	−16.7	−16.1	−13.5	−13.4	−12.5	−7.8	−8.2	−7.9	1.4	2.3
555	−16.7	−16.2	−13.6	−13.4	−12.6	−7.9	−8.2	−8.0	1.3	2.2
560	−16.7	−16.3	−13.7	−13.5	−12.7	−8.0	−8.3	−8.1	1.3	2.2
565	−16.6	−16.4	−13.8	−13.5	−12.8	−8.0	−8.4	−8.2	1.2	2.1
570	−16.6	−16.4	−13.9	−13.5	−12.9	−8.1	−8.5	−8.2	1.1	2.1
575	−16.5	−16.5	−14.0	−13.5	−13.0	−8.2	−8.6	−8.3	1.1	2.0
580	−16.5	−16.6	−14.1	−13.5	−13.1	−8.3	−8.7	−8.4	1.0	2.0
585	−16.4	−16.7	−14.2	−13.5	−13.1	−8.4	−8.7	−8.5	0.9	2.0
590	−16.3	−16.8	−14.2	−13.5	−13.2	−8.5	−8.8	−8.6	0.9	1.9
595	−16.2	−16.9	−14.3	−13.5	−13.3	−8.6	−8.9	−8.6	0.8	1.9
600	−16.3	−16.9	−14.4	−13.5	−13.4	−8.7	−9.0	−8.7	0.8	1.8
605	−16.4	−17.0	−14.5	−13.6	−13.4	−8.8	−9.1	−8.8	0.7	1.8
610	−16.6	−17.1	−14.6	−13.7	−13.5	−8.8	−9.1	−8.9	0.7	1.8
615	−16.7	−17.2	−14.7	−13.8	−13.6	−8.9	−9.2	−8.9	0.6	1.6
620	−16.8	−17.2	−14.7	−13.9	−13.7	−9.0	−9.3	−9.0	0.5	1.4
625	−16.9	−17.3	−14.8	−13.9	−13.8	−9.1	−9.4	−9.1	0.5	1.2
630	−17.0	−17.4	−14.9	−14.0	−13.8	−9.2	−9.4	−9.1	0.4	1.1
635	−17.1	−17.5	−15.0	−14.1	−13.9	−9.2	−9.5	−9.2	0.4	0.9
640	−17.2	−17.5	−15.1	−14.2	−14.0	−9.3	−9.6	−9.2	0.3	0.7
645	−17.4	−17.6	−15.1	−14.3	−14.0	−9.4	−9.6	−9.3	0.3	0.6
650	−17.5	−17.7	−15.2	−14.4	−14.1	−9.5	−9.7	−9.3	0.2	0.4
655	−17.6	−17.8	−15.3	−14.4	−14.2	−9.6	−9.8	−9.3	0.2	0.3
660	−17.7	−17.8	−15.4	−14.5	−14.3	−9.6	−9.9	−9.4	0.1	0.1
665	−17.8	−17.9	−15.4	−14.6	−14.3	−9.7	−9.9	−9.4	0.1	0.0
670	−17.9	−18.0	−15.5	−14.7	−14.4	−9.8	−10.0	−9.5	0.0	−0.2

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m **h_1, m**	**3** **1**	**3** **1.5**	**5** **1**	**5** **1.5**	**5** **2**	**10** **1**	**10** **1.5**	**10** **2.5**	**30** **1**	**30** **1.5**
f_M (MHz)	**A_N (dB)**									
675	−18.0	−18.0	−15.6	−14.8	−14.5	−9.9	−10.1	−9.5	0.0	−0.3
680	−18.1	−18.1	−15.7	−14.8	−14.5	−9.9	−10.1	−9.6	−0.1	−0.4
685	−18.2	−18.2	−15.7	−14.9	−14.6	−10.0	−10.2	−9.7	−0.1	−0.5
690	−18.2	−18.2	−15.8	−15.0	−14.7	−10.1	−10.3	−9.7	−0.2	−0.7
695	−18.3	−18.3	−15.9	−15.1	−14.7	−10.2	−10.3	−9.8	−0.2	−0.8
700	−18.4	−18.4	−15.9	−15.1	−14.8	−10.2	−10.4	−9.9	−0.3	−0.9
705	−18.5	−18.4	−16.0	−15.2	−14.9	−10.3	−10.5	−9.9	−0.3	−1.0
710	−18.6	−18.4	−16.1	−15.3	−14.9	−10.4	−10.5	−10.0	−0.4	−1.1
715	−18.7	−18.4	−16.1	−15.3	−15.0	−10.4	−10.6	−10.1	−0.4	−1.2
720	−18.8	−18.4	−16.2	−15.4	−15.1	−10.5	−10.7	−10.1	−0.5	−1.3
725	−18.9	−18.4	−16.3	−15.5	−15.1	−10.6	−10.7	−10.2	−0.5	−1.4
730	−18.9	−18.4	−16.3	−15.6	−15.2	−10.6	−10.8	−10.2	−0.5	−1.4
735	−19.0	−18.4	−16.4	−15.6	−15.2	−10.7	−10.8	−10.3	−0.6	−1.5
740	−19.1	−18.5	−16.5	−15.7	−15.3	−10.8	−10.9	−10.4	−0.6	−1.6
650	−17.5	−17.7	−15.2	−14.4	−14.1	−9.5	−9.7	−9.3	0.2	0.4
655	−17.6	−17.8	−15.3	−14.4	−14.2	−9.6	−9.8	−9.3	0.2	0.3
660	−17.7	−17.8	−15.4	−14.5	−14.3	−9.6	−9.9	−9.4	0.1	0.1
665	−17.8	−17.9	−15.4	−14.6	−14.3	−9.7	−9.9	−9.4	0.1	0.0
670	−17.9	−18.0	−15.5	−14.7	−14.4	−9.8	−10.0	−9.5	0.0	−0.2
675	−18.0	−18.0	−15.6	−14.8	−14.5	−9.9	−10.1	−9.5	0.0	−0.3
680	−18.1	−18.1	−15.7	−14.8	−14.5	−9.9	−10.1	−9.6	−0.1	−0.4
685	−18.2	−18.2	−15.7	−14.9	−14.6	−10.0	−10.2	−9.7	−0.1	−0.5
690	−18.2	−18.2	−15.8	−15.0	−14.7	−10.1	−10.3	−9.7	−0.2	−0.7
695	−18.3	−18.3	−15.9	−15.1	−14.7	−10.2	−10.3	−9.8	−0.2	−0.8
700	−18.4	−18.4	−15.9	−15.1	−14.8	−10.2	−10.4	−9.9	−0.3	−0.9
705	−18.5	−18.4	−16.0	−15.2	−14.9	−10.3	−10.5	−9.9	−0.3	−1.0
710	−18.6	−18.4	−16.1	−15.3	−14.9	−10.4	−10.5	−10.0	−0.4	−1.1
715	−18.7	−18.4	−16.1	−15.3	−15.0	−10.4	−10.6	−10.1	−0.4	−1.2
720	−18.8	−18.4	−16.2	−15.4	−15.1	−10.5	−10.7	−10.1	−0.5	−1.3
725	−18.9	−18.4	−16.3	−15.5	−15.1	−10.6	−10.7	−10.2	−0.5	−1.4
730	−18.9	−18.4	−16.3	−15.6	−15.2	−10.6	−10.8	−10.2	−0.5	−1.4
735	−19.0	−18.4	−16.4	−15.6	−15.2	−10.7	−10.8	−10.3	−0.6	−1.5
740	−19.1	−18.5	−16.5	−15.7	−15.3	−10.8	−10.9	−10.4	−0.6	−1.6
745	−19.2	−18.6	−16.5	−15.8	−15.4	−10.8	−11.0	−10.4	−0.7	−1.7
750	−19.3	−18.7	−16.6	−15.8	−15.4	−10.9	−11.0	−10.5	−0.7	−1.7
755	−19.4	−18.7	−16.7	−15.9	−15.5	−11.0	−11.1	−10.6	−0.7	−1.8
760	−19.4	−18.8	−16.7	−16.0	−15.6	−11.0	−11.1	−10.6	−0.8	−1.8
765	−19.5	−18.9	−16.8	−16.0	−15.6	−11.1	−11.2	−10.7	−0.8	−1.9
770	−19.6	−18.9	−16.9	−16.1	−15.7	−11.2	−11.3	−10.7	−0.9	−2.0
775	−19.7	−19.0	−16.9	−16.2	−15.7	−11.2	−11.3	−10.8	−0.9	−2.0
780	−19.7	−19.1	−17.0	−16.2	−15.8	−11.3	−11.4	−10.9	−0.9	−2.1
785	−19.8	−19.1	−17.0	−16.3	−15.8	−11.3	−11.4	−10.9	−1.0	−2.1
790	−19.9	−19.2	−17.1	−16.3	−15.9	−11.4	−11.5	−11.0	−1.0	−2.2
795	−20.0	−19.3	−17.1	−16.4	−16.0	−11.5	−11.6	−11.0	−1.1	−2.3
800	−20.0	−19.3	−17.2	−16.5	−16.0	−11.5	−11.6	−11.1	−1.1	−2.3

Table D.6—Theoretical NSA for an ideal site (most commonly used geometries for broadband antennas, vertical polarization)[a,b,c] (see D.1); frequency step sizes are per D.5 (swept frequency method); h_2 = 1 m to 4 m (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
R, m h_1, m	3 1	3 1.5	5 1	5 1.5	5 2	10 1	10 1.5	10 2.5	30 1	30 1.5
f_M (MHz)	A_N (dB)									
805	−20.1	−19.4	−17.2	−16.5	−16.1	−11.6	−11.7	−11.1	−1.1	−2.4
810	−20.2	−19.4	−17.2	−16.6	−16.1	−11.6	−11.7	−11.2	−1.2	−2.4
815	−20.2	−19.5	−17.3	−16.6	−16.2	−11.7	−11.8	−11.3	−1.2	−2.5
820	−20.3	−19.6	−17.3	−16.7	−16.2	−11.8	−11.8	−11.3	−1.2	−2.5
825	−20.4	−19.6	−17.3	−16.8	−16.3	−11.8	−11.9	−11.4	−1.3	−2.6
830	−20.4	−19.7	−17.3	−16.8	−16.3	−11.9	−11.9	−11.4	−1.3	−2.6
835	−20.5	−19.7	−17.3	−16.9	−16.3	−11.9	−12.0	−11.5	−1.3	−2.7
840	−20.6	−19.8	−17.4	−16.9	−16.3	−12.0	−12.1	−11.5	−1.4	−2.8
845	−20.6	−19.9	−17.4	−17.0	−16.3	−12.0	−12.1	−11.6	−1.4	−2.8
850	−20.7	−19.9	−17.4	−17.1	−16.4	−12.1	−12.2	−11.6	−1.4	−2.9
855	−20.8	−20.0	−17.4	−17.1	−16.4	−12.2	−12.2	−11.7	−1.4	−2.9
860	−20.8	−20.0	−17.4	−17.2	−16.5	−12.2	−12.3	−11.7	−1.5	−3.0
865	−20.9	−20.1	−17.3	−17.2	−16.5	−12.3	−12.3	−11.8	−1.5	−3.0
870	−21.0	−20.1	−17.3	−17.3	−16.6	−12.3	−12.4	−11.8	−1.5	−3.1
875	−21.0	−20.2	−17.3	−17.3	−16.6	−12.4	−12.4	−11.9	−1.6	−3.1
880	−21.1	−20.2	−17.3	−17.4	−16.7	−12.4	−12.5	−11.9	−1.6	−3.2
885	−21.1	−20.3	−17.3	−17.4	−16.7	−12.5	−12.5	−12.0	−1.6	−3.2
890	−21.2	−20.4	−17.2	−17.5	−16.8	−12.5	−12.6	−12.1	−1.6	−3.3
895	−21.3	−20.4	−17.3	−17.6	−16.8	−12.6	−12.6	−12.1	−1.7	−3.3
900	−21.3	−20.5	−17.4	−17.6	−16.9	−12.6	−12.7	−12.2	−1.7	−3.4
905	−21.4	−20.5	−17.4	−17.7	−16.9	−12.7	−12.7	−12.2	−1.7	−3.4
910	−21.4	−20.6	−17.5	−17.7	−17.0	−12.7	−12.8	−12.3	−1.8	−3.5
915	−21.5	−20.6	−17.5	−17.8	−17.0	−12.8	−12.8	−12.3	−1.8	−3.5
920	−21.6	−20.7	−17.6	−17.8	−17.1	−12.8	−12.9	−12.4	−1.9	−3.6
925	−21.6	−20.7	−17.7	−17.9	−17.1	−12.9	−12.9	−12.4	−2.0	−3.6
930	−21.7	−20.8	−17.7	−17.9	−17.2	−12.9	−13.0	−12.4	−2.1	−3.7
935	−21.7	−20.8	−17.8	−18.0	−17.2	−13.0	−13.0	−12.5	−2.2	−3.7
940	−21.8	−20.9	−17.8	−18.0	−17.3	−13.0	−13.1	−12.5	−2.4	−3.8
945	−21.8	−20.9	−17.9	−18.1	−17.3	−13.1	−13.1	−12.6	−2.5	−3.8
950	−21.9	−21.0	−18.0	−18.1	−17.4	−13.1	−13.2	−12.6	−2.6	−3.9
955	−22.0	−21.0	−18.0	−18.2	−17.4	−13.2	−13.2	−12.7	−2.7	−3.9
960	−22.0	−21.1	−18.1	−18.2	−17.5	−13.2	−13.3	−12.7	−2.8	−4.0
965	−22.1	−21.1	−18.1	−18.3	−17.5	−13.3	−13.3	−12.8	−2.9	−4.0
970	−22.1	−21.2	−18.2	−18.3	−17.6	−13.3	−13.3	−12.8	−3.0	−4.0
975	−22.2	−21.2	−18.2	−18.4	−17.6	−13.4	−13.4	−12.9	−3.1	−4.1
980	−22.2	−21.3	−18.3	−18.4	−17.7	−13.4	−13.4	−12.9	−3.2	−4.1
985	−22.3	−21.3	−18.4	−18.5	−17.7	−13.5	−13.5	−13.0	−3.3	−4.2
990	−22.3	−21.3	−18.4	−18.5	−17.8	−13.5	−13.5	−13.0	−3.4	−4.2
995	−22.4	−21.4	−18.5	−18.6	−17.8	−13.6	−13.6	−13.1	−3.5	−4.3
1000	−22.4	−21.4	−18.5	−18.6	−17.9	−13.6	−13.6	−13.1	−3.6	−4.3

[a] This data applies for antennas with 25 cm or more clearance to the ground plane when the center of the antenna is 1 m above the ground plane, and antennas with 25 cm or more clearance to the covering or absorbers on walls or ceiling for alternative test sites.
[b] For geometries other than those listed, the theoretical NSA values for an ideal site shall be calculated as per D.7.
[c] *GSCF* values obtained per ANSI C63.5 shall be inserted in Equation (D.2) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

The existing Table D.2 in D.7 of ANSI C63.4-2014, and its caption, are changed as shown in the following Table D.7. In the new Table D.7, the four columns (1) to (4) of the former Table D.2 are repeated as columns (1), (2), (4), and (5), respectively, column (3) is inserted, and rows for additional frequencies are inserted per the increments specified in D.4 (discrete frequency method).

Table D.7—Theoretical NSA for an ideal site (geometries for tuned dipoles, horizontal polarization); h_1 = 2 m; h_2 = 1 m to 4 m (see D.1)

(1)	(2)	(3)	(4)	(5)
***R*, m**	**3 [a]**	**5**	**10**	**30**
f_M (MHz)	**A_N (dB)**			
30	11.0	15.6	24.1	41.7
35	8.8	13.3	21.6	39.1
40	7.0	11.4	19.4	36.8
45	5.5	9.8	17.5	34.7
50	4.2	8.5	15.9	32.9
55	3.1	7.3	14.4	31.3
60	2.2	6.3	13.1	29.8
65	1.3	5.4	12.0	28.4
70	0.6	4.6	10.9	27.2
75	−0.1	3.9	10.0	26.0
80	−0.7	3.2	9.2	24.9
85	−1.3	2.6	8.4	23.9
90	−1.8	2.0	7.8	23.0
95	−2.3	1.5	7.2	22.1
100	−2.8	1.0	6.7	21.2
105	−3.2	0.5	6.2	20.4
110	−3.6	0.1	5.8	19.7
115	−4.0	−0.3	5.4	18.9
120	−4.4	−0.7	5.0	18.2
125	−4.8	−1.1	4.6	17.6
130	−5.1	−1.5	4.2	17.0
135	−5.4	−1.8	3.8	16.4
140	−5.8	−2.1	3.5	15.8
145	−6.0	−2.4	3.2	15.3
150	−6.3	−2.8	2.9	14.7
155	−6.5	−3.1	2.6	14.2
160	−6.7	−3.3	2.3	13.8
165	−6.8	−3.6	2.0	13.3
170	−6.9	−3.9	1.7	12.9
175	−7.0	−4.1	1.5	12.4
180	−7.2	−4.4	1.2	12.0
185	−7.5	−4.6	1.0	11.6
190	−7.8	−4.9	0.7	11.3

Table D.7—Theoretical NSA for an ideal site (geometries for tuned dipoles, horizontal polarization); h_1 = 2 m; h_2 = 1 m to 4 m (see D.1) *(continued)*

(1)	(2)	(3)	(4)	(5)
***R*, m**	**3** [a]	**5**	**10**	**30**
***f*$_M$ (MHz)**	A_N (dB)			
195	−8.1	−5.1	0.5	10.9
200	−8.4	−5.3	0.3	10.6
225	−9.6	−6.3	−0.8	9.0
250	−10.6	−6.7	−1.7	7.8
275	−11.5	−7.7	−2.6	6.8
300	−12.3	−8.5	−3.3	6.1
325	−13.0	−9.3	−4.0	5.4
350	−13.7	−10.0	−4.7	4.7
375	−14.3	−10.6	−5.3	4.1
400	−14.9	−11.2	−5.8	3.5
425	−15.4	−11.8	−6.3	3.0
450	−15.8	−12.3	−6.7	2.5
475	−16.3	−12.8	−7.2	2.0
500	−16.7	−13.3	−7.6	1.6
525	−17.2	−13.7	−8.1	1.2
550	−17.6	−14.1	−8.5	0.7
575	−18.0	−14.5	−8.9	0.4
600	−18.4	−14.9	−9.3	0.0
625	−18.7	−15.2	−9.6	−0.4
650	−19.1	−15.4	−10.0	−0.7
675	−19.4	−15.8	−10.3	−1.0
700	−19.7	−16.1	−10.7	−1.4
725	−20.0	−16.4	−11.0	−1.7
750	−20.3	−16.7	−11.3	−2.0
775	−20.6	−17.0	−11.6	−2.2
800	−20.9	−17.3	−11.8	−2.5
825	−21.1	−17.6	−12.1	−2.8
850	−21.4	−17.9	−12.4	−3.0
875	−21.7	−18.1	−12.6	−3.3
900	−21.9	−18.4	−12.9	−3.5
925	−22.2	−18.6	−13.1	−3.8
950	−22.4	−18.9	−13.4	−4.0
975	−22.6	−19.1	−13.6	−4.2
1000	−22.8	−19.3	−13.8	−4.5

[a] The mutual impedance correction factors in Table D.9 for horizontally polarized tuned dipoles spaced 3 m apart shall be inserted in Equation (D.1) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

The existing Table D.3 of D.7 of ANSI C63.4-2014, and its caption, are changed in the following new Table D.8. In the new Table D.8, the four columns (1) to (4) of the former Table D.3 are repeated as columns (1), (2), (4), and (5), respectively, column (3) is inserted, and rows for additional frequencies are inserted per the increments specified in D.4 (discrete frequency method).

Table D.8—Theoretical NSA for an ideal site (geometries for tuned dipoles, vertical polarization); h_1 = 2.75 m (see D.1)

(1)	(2)	(3)	(4)	(5)	(6)
f_M (MHz)	h_2(m)	R = 3 m [a]	R = 5 m	R = 10 m	R = 30 m
		A_N (dB)			
30	2.75−4	12.4	15.9	18.6	26.3
35	2.39−4	11.3	14.7	17.4	24.9
40	2.13−4	10.4	13.7	16.2	23.8
45	1.92−4	9.5	12.9	15.1	22.7
50	1.75−4	8.4	12.2	14.2	21.8
55	1.625−4	7.4	11.6	13.4	21.0
60	1.50−4	6.3	11.0	12.6	20.2
65	1.41−4	5.3	10.5	12.0	19.5
70	1.32−4	4.4	9.6	11.3	18.9
75	1.255−4	3.5	8.4	10.8	18.3
80	1.19−4	2.8	7.3	10.2	17.7
85	1.135−4	2.1	6.4	9.7	17.2
90	1.08−4	1.6	5.6	9.2	16.7
95	1.04−4	1.1	4.9	8.8	16.2
100	1−4	0.6	4.2	8.4	15.8
105	1−4	0.2	3.6	8.1	15.4
110	1−4	−0.1	3.1	7.9	15.0
115	1−4	−0.4	2.6	7.7	14.6
120	1−4	−0.7	2.1	7.5	14.3
125	1−4	−0.9	1.7	7.3	14.0
130	1−4	−1.1	1.3	6.7	13.6
135	1−4	−1.3	0.9	6.1	13.3
140	1−4	−1.5	0.6	5.5	13.0
145	1−4	−1.7	0.2	5.0	12.8
150	1−4	−2.0	−0.1	4.7	12.5
155	1−4	−2.6	−0.4	4.3	12.2
160	1−4	−3.0	−0.7	3.9	12.0
165	1−4	−3.4	−1.0	3.6	11.7
170	1−4	−3.8	−1.2	3.3	11.5
175	1−4	−4.1	−1.5	3.0	11.3
180	1−4	−4.5	−1.8	2.7	11.1
185	1−4	−4.7	−2.0	2.4	10.9

Table D.8—Theoretical NSA for an ideal site (geometries for tuned dipoles, vertical polarization); h_1 = 2.75 m (see D.1) (*continued*)

(1)	(2)	(3)	(4)	(5)	(6)
f_M (MHz)	h_2(m)	R = 3 m [a]	R = 5 m	R = 10 m	R = 30 m
		A_N (dB)			
190	1−4	−5.0	−2.2	2.1	10.7
195	1−4	−5.2	−2.5	1.8	10.5
200	1−4	−5.4	−2.7	1.6	10.3
225	1−4	−6.2	−3.7	0.4	9.4
250	1−4	−7.0	−4.6	−0.6	8.7
275	1−4	−8.2	−5.4	−1.5	8.1
300	1−4	−8.9	−6.2	−2.3	7.6
325	1−4	−9.5	−6.9	−3.1	7.2
350	1−4	−10.1	−7.5	−3.7	6.0
375	1−4	−10.9	−8.1	−4.4	4.8
400	1−4	−11.4	−8.7	−5.0	3.9
425	1−4	−11.9	−9.2	−5.5	3.3
450	1−4	−12.4	−9.7	−6.0	2.7
475	1−4	−12.9	−10.2	−6.5	2.3
500	1−4	−13.4	−10.6	−6.9	1.8
525	1−4	−13.7	−11.1	−7.4	1.4
550	1−4	−14.2	−11.5	−7.8	0.9
575	1−4	−14.6	−11.9	−8.2	0.5
600	1−4	−14.9	−12.2	−8.4	0.2
625	1−4	−15.2	−12.6	−8.7	−0.2
650	1−4	−15.6	−12.9	−9.1	−0.5
675	1−4	−16.0	−13.3	−9.4	−0.9
700	1−4	−16.3	−13.6	−9.8	−1.2
725	1−4	−16.6	−13.9	−10.1	−1.5
750	1−4	−16.9	−14.2	−10.4	−1.8
775	1−4	−17.2	−14.4	−10.7	−2.1
800	1−4	−17.4	−14.7	−11.0	−2.4
825	1−4	−17.7	−15.0	−11.3	−2.6
850	1−4	−18.0	−15.3	−11.5	−2.9
875	1−4	−18.2	−15.5	−11.8	−3.2
900	1−4	−18.5	−15.7	−12.0	−3.4
925	1−4	−18.7	−16.0	−12.3	−3.7
950	1−4	−18.9	−16.2	−12.5	−3.9
975	1−4	−19.2	−16.4	−12.7	−4.1
1000	1−4	−19.4	−16.7	−13.0	−4.3

[a] The mutual impedance correction factors in Table D.9 for vertically polarized tuned dipoles spaced 3 m apart shall be inserted in Equation (D.1) (see D.2.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Change Table D.4 of ANSI C63.4-2014 as follows, and renumber it as Table D.9.

Table D.9—Mutual impedance correction factors (ΔAF_{TOT}) for setups using two Roberts tuned dipoles; R = 3 m[a,b,c] (see D.2.1)

(1)	(2)	(3)
f_M MHz	**Horizontal Polarization** h_1 = 2 m h_2 = 1 m to 4 m scan	**Vertical Polarization** h_1 = 2.75 m h_2 = (see Table D.8)
	ΔAF_{TOT} (dB)	
30	3.1	2.9
35	4.0	2.6
40	4.1	2.1
45	3.3	1.6
50	2.8	1.5
60	1.0	2.0
70	−0.4	1.5
80	−1.0	0.9
90	−1.0	0.7
100	−1.2	0.1
120	−0.4	−0.2
140	−0.1	0.2
160	−1.5	0.5
180	−1.0	−0.4

NOTE—These mutual impedance correction factors at the given frequencies were calculated for resonant (tuned) dipoles with reference antenna baluns using method-of-moments numerical computations (Berry et al. [B8]). The associated theoretical free-space antenna factors (FSAFs) are for ideal resonant (tuned) dipoles with an assumed 0.5 dB balun loss (each antenna). If the actual balun loss is known, it can be used to provide an appropriate modification to each antenna factor used in arriving at the correction factors in this table. See the information on FSAF and Roberts tuned dipole reference antenna in ANSI C63.5. These correction factors do not completely describe antenna factors measured above a ground plane (e.g., at heights of 3 m or 4 m), because these antenna factors differ from FSAFs at the lower frequencies. However, within the error bounds used to establish the NSA criteria of 5.4.4.2 of ANSI C63.4-2014 (Bronaugh [B9]),[33] and for baluns with loss substantially less than or equal to 0.5 dB, the values are adequate to indicate site anomalies.

[a] Users are cautioned that when using resonant half-wavelength tuned dipoles and/or antennas with baluns that differ from the Roberts tuned dipole reference antenna and baluns, different ΔAF_{TOT} correction factors may be required.
[b] The mutual impedance correction factors shall be inserted in Equation (D.1) (see D.2.1) in determining the 3 m measured NSA data for comparison with the theoretical NSA values for an ideal site given in Table D.7 and Table D.8. For 5 m, 10 m, and 30 m separation distance measurement geometries, site adequacy can be assessed by considering the mutual impedance correction factors to be equal to zero ($\Delta AF_{TOT} = 0$).[c] For frequencies within 30 MHz to 180 MHz other than those shown in this table, ΔAF_{TOT} correction factors shall be calculated using linear interpolation between the tabulated values.

[33] Information in Bronaugh [B9] concerning derivation of the NSA criterion was also contained in ANSI C63.6-1996 [B2], which was withdrawn because the criteria is a requirement in ANSI C63.4 without the need for a separate standard to show where the requirement came from.

Replace Figure D.1 through Figure D.6 of ANSI C63.4-2014 and update figure captions as follows:

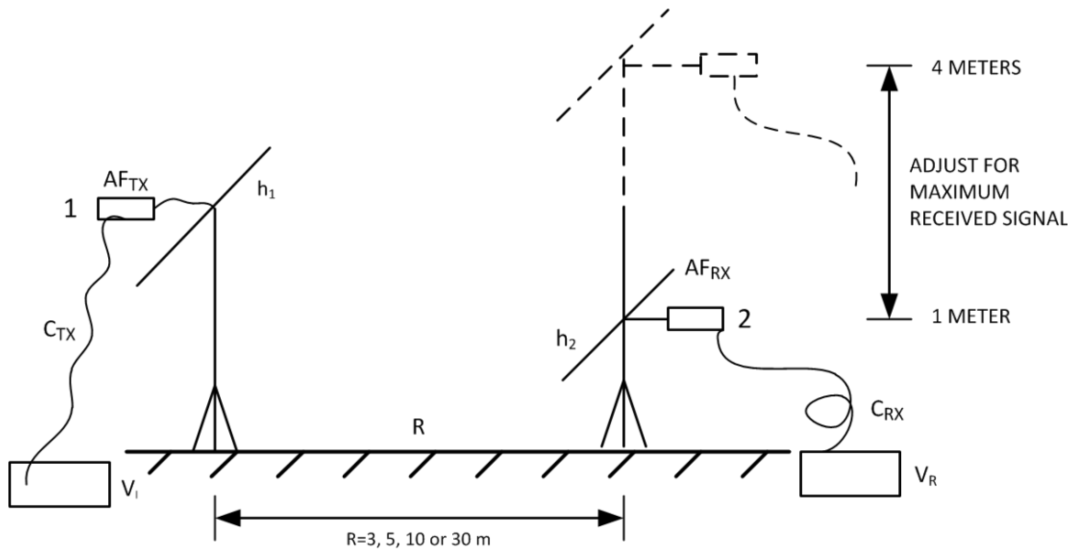


Figure D.1—Site attenuation measurement geometry: horizontal polarization; broadband or tuned dipole antennas (D.2 describes the setup)

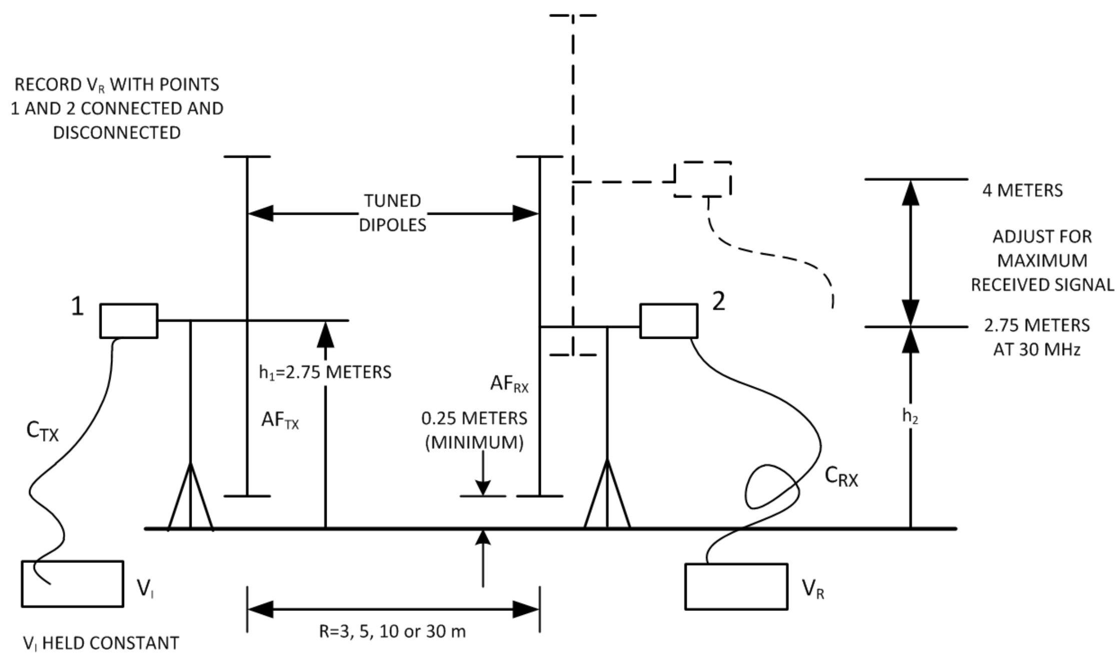
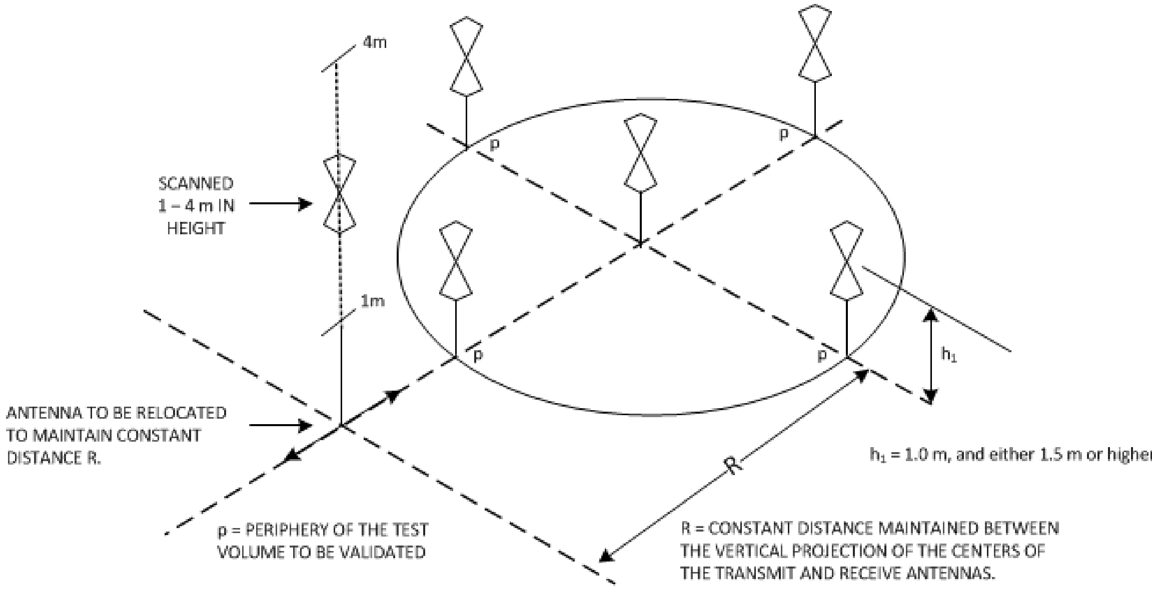
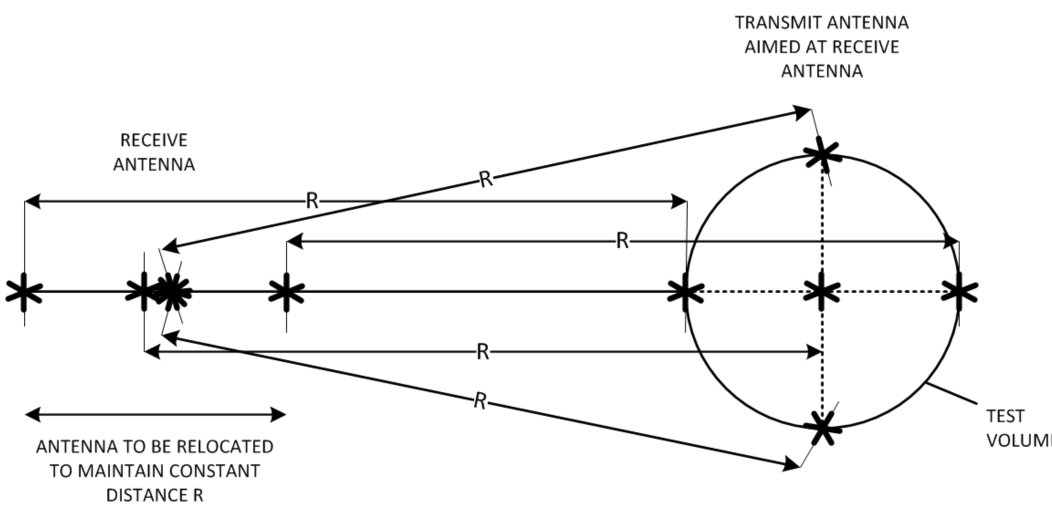


Figure D.2—Site attenuation measurement geometry: vertical polarization using tuned dipole antennas (D.2 describes the setup); the minimum h_2 varies with frequency as shown in Table D.8



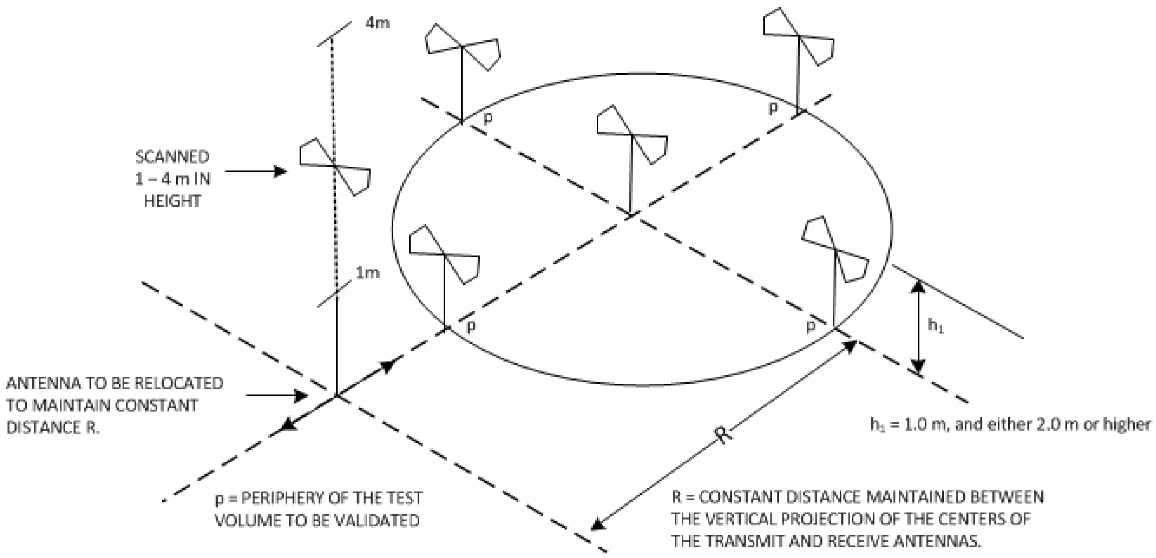
a) perspective view



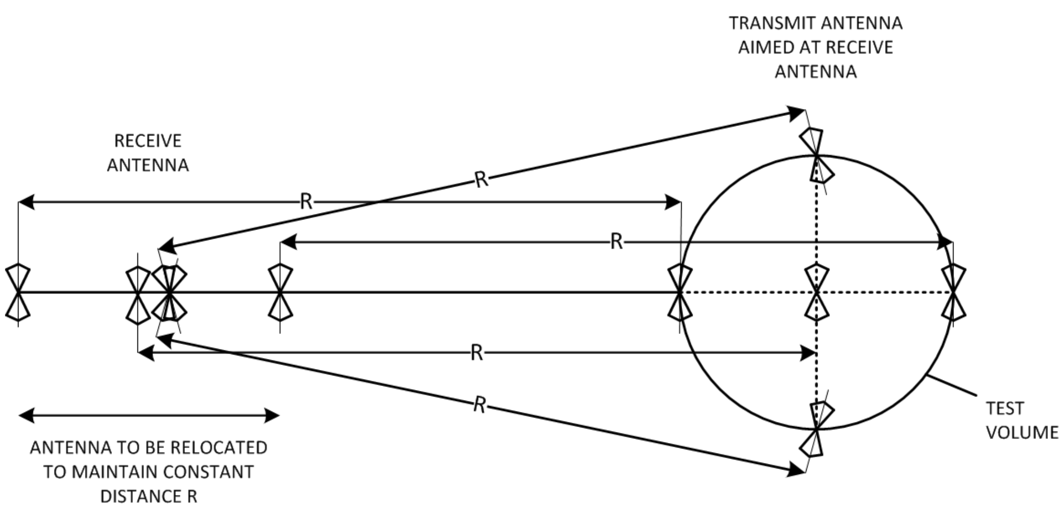
b) top view

Figure D.3—Typical antenna positions for alternative test sites: vertical polarization NSA measurements; a) perspective view, b) top view (D.3 describes the setup and antenna orientation adjustments)

NOTE—In practice, re-orientation (aiming, e.g., as shown in Figure D.4 for horizontal polarization) is not needed for biconical antennas in vertical polarization, due to their symmetric omnidirectional antenna patterns in vertical polarization. Regardless, for consistency, asterisk-like symbols are used in Figure D.3 b) to depict the antennas in vertical polarization, corresponding to end-on views of typical wire-cage-element biconical antennas. Representation using this symbol for biconical antennas was chosen for reasons of clarity, rather than showing a setup with LPDA antennas in vertical polarization, for which as seen in a top view the antennas would simply be line segments.



a) perspective view



b) top view

Figure D.4—Typical antenna positions for alternative test sites: horizontal polarization NSA measurements; a) perspective view, b) top view (D.3 describes the setup and antenna orientation adjustments)

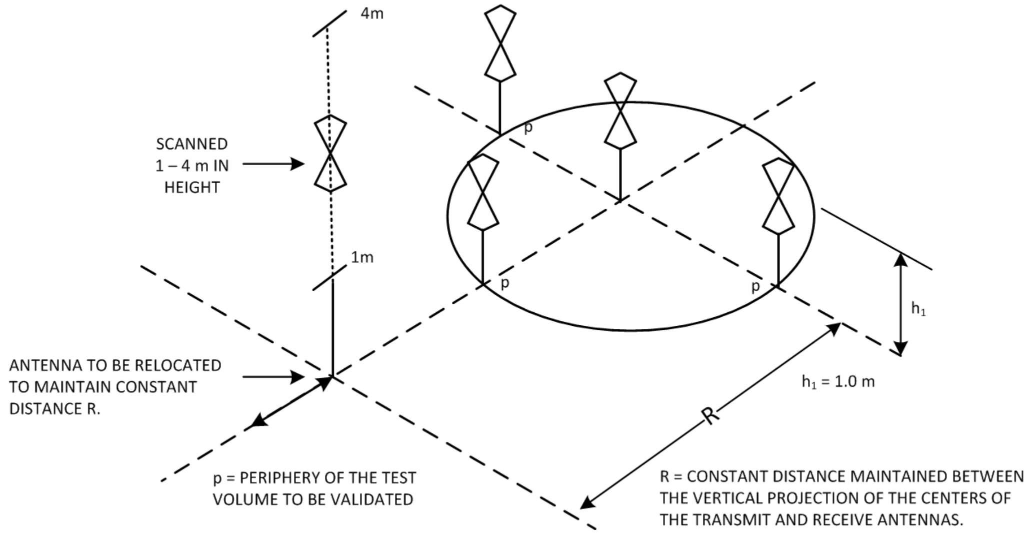


Figure D.5—Typical antenna positions for alternative test sites: vertical polarization NSA measurements for an EUT that does not exceed a volume of 1.2 m diameter and 1.5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections (D.3 describes the setup)

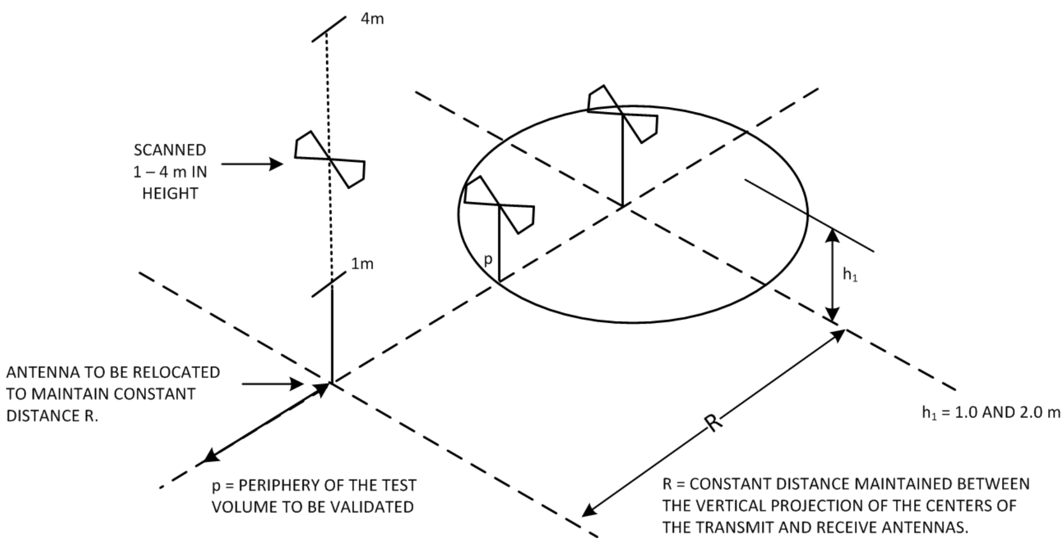


Figure D.6—Typical antenna positions for alternative test sites: horizontal polarization NSA measurements for an EUT that does not exceed a volume of 1.2 m diameter and 1.5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections (D.3 describes the setup)

Renumber Table D.5, Table D.6, and Table D.7 of ANSI C63.4-2014 as as Table D.10, Table D.11, and Table D.12 and change as follows.

Table D.10—Site attenuation worksheet (see D.4 and D.5)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Frequency (MHz)	**Polarization H or V**	**V_{Direct} (dBμV)**	**V_{Site} (dBμV)**	**ΔAF_{TOT} [a] (see Table D.9) (dB)**	**Adjusted site attenuation (dB)**	**AF_T (dB) (1/m)**	**AF_R (dB) (1/m)**	**A_N (NSA) Measured (dB)**	**A_N (NSA) Theoretical (dB)**	**Deviation (dB)**

NOTE—Column operations are as follows:	REMARKS:
(6) = (3)−(4)−(5) (9) = (6)−(7)−(8) (10) = See Table D.3 through Table D.6, or Table D.7 and Table D.8 (11) = (9)−(10)	

[a] Replace ΔAF_{TOT} with *GSCF* when using broadband antennas.

Table D.11—Descriptions of column headings used in Table D.10

Column #	Description of column heading
(1)	Frequency between 30 MHz and 1000 MHz as indicated in D.4 (discrete frequency method) or D.5 (swept frequency method).
(2)	The polarizations of both transmit and receive antennas with respect to the reference ground plane.
(3)	V_{Direct} is the level at the receiver or spectrum analyzer when the coaxial feed lines connected to each antenna are directly connected together (points 1 and 2 connected in Figure D.1 and Figure D.2) (dBμV).
(4)	V_{Site} is the level measured at the receiver or spectrum analyzer when the receive antenna is searched in height for the maximum transmitted signal that is required for site attenuation measurements. The level of the signal generator is the same as for the Column (3) measurement (dBμV).
(5)	$\Delta AF_{\mathrm{TOT}} = 0$ for all vertical and horizontal site attenuation measurements made at separation distances of 5 m, 10 m, and 30 m with tuned dipoles. For site attenuation measurements at 3 m separation using tuned dipoles, ΔAF_{TOT} is given in Table D.9. For broadband antennas, ΔAF_{TOT} shall be replaced by *GSCF* (see D.2.1 and D.2.2).
(6)	A = Site attenuation [algebraic sum of Column (3) minus Column (4) minus Column (5)] [dB].
(7)	AF_{T} = Transmit antenna factor (accurately measured for this antenna) [dB (1/m)].
(8)	AF_{R} = Receive antenna factor (accurately measured for this antenna) [dB (1/m)].
(9)	A_{N} = Measured NSA [Column (6) minus Column (7) minus Column (8)]. This is equivalent to A_{N} given by Equation (D.1) [dB] (see D.2.1).
(10)	Theoretical NSA (see appropriate values for site attenuation geometry and antennas used in Table D.3 through Table D.6, or in Table D.7 and Table D.8).
(11)	Deviation = Column (9) minus Column (10) [dB].

Table D.12—Example NSA worksheet entries (see D.4)

Column #	Entry
(1)	80 MHz frequency
(2)	Horizontal (polarization)
(3)	81.5 dBμV (assumed value); Receiver/spectrum analyzer reading with coaxial cables connected
(4)	67.5 dBμV (assumed value); Receiver/spectrum analyzer reading with receiver signal maximized by searching the height between 1 m and 4 m
(5)	−1.0 dB (from Table D.9)
(6)	15.0 dB [81.5 − 67.5 − (−1.0)]
(7)	6.7 dB (1/m) assumed from calibration curve
(8)	6.5 dB (1/m) assumed from calibration curve
(9)	1.8 dB (15.0 − 6.7 − 6.5)
(10)	−0.7 dB (from Table D.7)
(11)	2.5 dB [1.8 − (−0.7)] (calculated deviation from theoretical NSA model)
NOTE—The Column (6) value of 15.0 dB is equivalent to the site attenuation for resonant half-wave tuned dipoles. The NSA removes the antenna factor and allows the comparison with the NSA for an ideal site. Column (11), hence, gives deviation amplitude of 2.5 dB with respect to the ideal site attenuation, which shows that at this frequency the example site meets the site validation requirements.	

Annex F

(informative)

Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)

Change F.6.1 in Annex F, including Equation (F.3), as follows:

F.6 Test report

F.6.1 TEM waveguide to OATS validation data

The OATS and OATS-equivalent TEM waveguide data for the measurement data sets at each facility shall be recorded in tabular form with parallel columns in units of dBμV/m. Measurement data from the TEM waveguide shall be transformed to OATS-equivalent field strength, calculated for the test distance used at the OATS. Wilson [B30] describes the conventional one-port TEM cell three-position correlation algorithm used for computation of OATS-equivalent field strength. If a different correlation algorithm is used, the test report shall include a description of the correlation algorithm and the reasons for its use.

The averages of the OATS and TEM waveguide data at each measured frequency shall be calculated. When calculating these averages, the field strength readings shall be converted from logarithmic values, dBμV/m, to linear values, μV/m. The ratio of the averages of the TEM waveguide and OATS measurements shall be calculated. The same detector function (peak, quasi-peak, or average) shall be used for each frequency in the OATS to TEM waveguide comparison.

The mean and standard deviation of the differences shall be calculated using the formulas listed below. The average of the TEM waveguide readings at a single frequency is designated as g_i. The average of the OATS readings at the same frequency is designated as o_i. The number of frequencies compared is n, with n greater than or equal to 10. The difference of the averages x_i is given by the equation

$$x_i = g_i - o_i \tag{F.1}$$

The mean $\bar{x}$ is given by the equation

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{F.2}$$

The standard deviation s is calculated with the equation

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{(n-1)}} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - n\left(\bar{x}\right)^2}{(n-1)}} \tag{F.3}$$

A sample spreadsheet calculation is shown in Table G.1.[34]

---

[34] The notation used in Equation (F.3) differs slightly from that of, e.g., Hart et al. [B52], which uses the symbols μ and σ rather than $\bar{x}$ and s, respectively.

In theory, comparisons shall be made between emissions at exactly the same frequency value. In practice, certain frequency values may differ slightly between the TEM waveguide and the OATS data. This shift in frequency values is caused by EUT instability and measurement system frequency uncertainty. Some judgment is necessary in selecting the correct peaks for comparison. For example, in harmonic-rich spectrum, such as is characteristic of many digital devices, the highest peak may shift from one harmonic to another. For these reasons, it is important to record the frequency as well as the amplitude for each frequency compared. An explanation of the rationale for the selected comparison shall be recorded in the test report.

Annex G

(informative)

Sample OATS to TEM waveguide validation spreadsheet

Replace the unnumbered table and Table G.1 in Annex G as follows:

The data and calculations for a TEM waveguide to OATS validation can easily be analyzed using a spreadsheet approach. The sample spreadsheet in Table G. lists the frequency and amplitude of field strength measurements made at each facility, calculates the average of the readings, calculates the difference between the averages, and calculates the mean and standard deviation of the TEM waveguide to OATS differences.

Column #	Entry
(1)	Frequency of each reading from the TEM waveguide (in MHz).
(2) to (4)	Amplitude of each reading from the TEM waveguide (in dBμV/m) (assumes three independent readings).
(5)	Average of the TEM waveguide amplitude readings (in μV/m). This average is calculated from the linear value, not the logarithmic value. Column (2) to Column (4) first shall be converted from dBμV/m to μV/m. $\text{Average} = \left[10^{(\text{reading}_1/20)} + 10^{(\text{reading}_2/20)} + 10^{(\text{reading}_3/20)}\right]/3$
(6)	Frequency of each reading taken at the OATS (in MHz).
(7) to (9)	Amplitude of each reading taken at the OATS (in dBμV/m). These readings shall be the maximum of the horizontal and vertical polarization readings at each frequency. Assumes three independent readings.
(10)	Average of the OATS amplitude readings (in μV/m). This average shall be calculated from the linear values, not the logarithmic values. Column (7) to Column (9) shall first be converted from dBμV/m to μV/m. $\text{Average} = \left[10^{(\text{reading}_1/20)} + 10^{(\text{reading}_2/20)} + 10^{(\text{reading}_3/20)}\right]/3$
(11)	Difference between TEM waveguide and OATS average amplitudes (in dB). The differences are calculated by 20 log |Column (5) / Column (10)|. $\text{Difference}_{\text{dB}} = 20\log\{[\text{Column (5) Average}]/[\text{Column (10) Average}]\}$
(12)	Mean and standard deviation of the differences (in dB). $\text{Mean}_{\text{dB}} = 20\log\left[\sum 10^{(\text{Difference}_{\text{dB}}/20)}/n\right]$ $\text{Standard Deviation}_{\text{dB}} = 20\log\sqrt{\dfrac{\sum\left[10^{(\text{Difference}_{\text{dB}}/20)} - 10^{(\text{Mean}_{\text{dB}}/20)}\right]^2}{n-1}}$

Table G.1—Sample spreadsheet

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)
TEM readings						**OATS readings**						**Summation**
Frequency (MHz)	**Field strength (dBμV/m)**			**Average (μV/m)**		**Frequency (MHz)**	**Field strength (dBμV/m)**			**Average (μV/m)**	**Difference (dB)**	**Mean & std. dev.**
	Scan 1	**Scan 2**	**Scan 3**				**Scan 1**	**Scan 2**	**Scan 3**			
frequency[a]	**reading**	**reading**	**reading**	**formula 1**		**frequency**	**reading**	**reading**	**reading**	**formula 2**	**formula 3**	
												Mean
												formula 4
												Std. Dev.
												formula 5
	formula 1 = $\{10^{[(\text{Column 2})/20]} + 10^{[(\text{Column 3})/20]} + 10^{[(\text{Column 4})/20]}\} / 3$											
	formula 2 = $\{(10^{[(\text{Column 7})/20]} + 10^{[(\text{Column 8})/20]} + 10^{[(\text{Column 9})/20]}\} / 3$											
	formula 3 = 20 log [(Column 5) / (Column 10)]											
	formula 4 = 20 log [SUM $(10^{(\text{column 11/20})}) / n$]											
	formula 5 = 20 log {SQRT [(SUM $[10^{(\text{Column 11/20})} - 10^{(\text{formula 4/20})}]^2$) / $(n - 1)$]}											
	n = number of frequencies compared											

[a] A minimum of the 10 frequencies with the highest amplitude readings, relative to the limit, at each facility shall be listed.

Annex N

(normative)

Test site-specific hybrid antenna qualification procedures, limitations and acceptance criteria

Replace N.4.3 as follows:

N.4 Test site-specific hybrid antenna qualification procedure

N.4.3 Test setup and test procedure

N.4.3.1 Test setup and test procedure for measurements made on 3 m test sites

This subclause is applicable to test sites that have the capability to make measurements only at a 3 m distance. This subclause is also applicable to 5 m and 10 m test sites, but the measurements described herein (and final compliance measurements made on products) shall be performed only at the 3 m distance. Refer to N.4.3.2 for the test setup and test procedures for measurements made on test sites at a 10 m distance.

a) Place the transmit biconical antenna in horizontal polarization at a height of 1 m at the center of the turntable. Install a 10 dB attenuator on the input connector of the transmit biconical antenna.

b) Place the receiving biconical antenna on the antenna mast in horizontal polarization at a height of 1 m at a distance of 3 m, as measured from the reference point of the transmit biconical antenna to the reference point of the receive biconical antenna. Do NOT use an attenuator on the output connector of the receiving biconical antenna. Use a high quality coaxial cable to connect the transmit biconical antenna (with the 10 dB attenuator installed) to a signal source. Use the coaxial cable that is used for regular product testing to connect the receiving antenna to the EMI receiver or spectrum analyzer via a 10 dB attenuator that shall be installed directly onto the input port of the EMI receiver or spectrum analyzer.

c) Scan the receiving biconical antenna from 1 m to 4 m while simultaneously scanning or stepping the EMI receiver or spectrum analyzer over the frequency range 30 MHz to 200 MHz. Use a maximum resolution bandwidth of 120 kHz. Use either linear frequency steps with maximum step-size equal to one-half of the chosen resolution bandwidth, or use a linear scan. Confirm that the received signal is at least 20 dB above the system noise floor. Record the maximum received signal levels. The results recorded are the reference values for the two biconical antennas at 3 m in horizontal polarization and are designated as $S_{21,\mathrm{BB3H}}$.

d) Without moving the transmit biconical antenna, remove the receiving biconical antenna and replace it with the hybrid antenna to be qualified, such that the reference point on the hybrid is at the 3 m distance, as measured from the reference point of the transmit biconical antenna. If required or desired in accordance with N.3 c), install the hybrid antenna impedance matching pad (HAIMP) attenuator at the output connector of the hybrid antenna. Designate the insertion loss of the HAIMP as L_{HAIMP}.

e) Reconnect the receiving coaxial cable, and repeat step c), making certain that the EMI receiver or spectrum analyzer settings are not changed. The results are the "antenna under test" (AUT) values of the transmit biconical antenna and the receiving hybrid antenna at 3 m in horizontal polarization. These results are designated as $S_{21,\mathrm{BH3H}}$.

f) Calculate the reference and AUT horizontally polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB3H}} = S_{21,\mathrm{BB3H}} + FSAF_{\mathrm{biconical}} \tag{N.1}$$

$$E_{\mathrm{BH3H}} = S_{21,\mathrm{BH3H}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \tag{N.2}$$

g) Calculate the difference between the reference and AUT horizontally polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{3mH}} = E_{\mathrm{BB3H}} - E_{\mathrm{BH3H}} \tag{N.3}$$

h) Compare the ΔE_{3mH} results obtained in step g) with the acceptance criteria given in N.5.1.

i) Repeat steps a) through g) with the biconical antennas and the hybrid antenna under test in vertical polarization at the 3 m measurement distance. Denote the reference and AUT vertically polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB3V}} = S_{21,\mathrm{BB3V}} + FSAF_{\mathrm{biconical}} \tag{N.4}$$

$$E_{\mathrm{BH3V}} = S_{21,\mathrm{BH3V}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \tag{N.5}$$

j) Calculate the difference between the reference and AUT vertically polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{3mV}} = E_{\mathrm{BB3V}} - E_{\mathrm{BH3V}} \tag{N.6}$$

k) Compare the ΔE_{3mV} results obtained in step j) with the acceptance criteria given in N.5.1.

N.4.3.2 Test setup and test procedure for measurements made on 10 m test sites

This subclause is applicable to test sites that have the capability to make measurements at a 10 m distance. Refer to N.4.3.1 for the test setup and test procedures for measurements made on 3 m or 5 m sites at a 3 m distance.

a) Place the transmit biconical antenna in horizontal polarization at a height of 1 m at the center of the turntable. Install a 10 dB attenuator on the input connector of the transmit biconical antenna.

b) Place the receiving biconical antenna on the antenna mast in horizontal polarization at a height of 1 m at a distance of 10 m, as measured from the reference point of the transmit biconical antenna to the reference point of the receive biconical antenna. Do NOT use an attenuator on the output connector of the receiving biconical antenna. Use a high quality coaxial cable to connect the transmit biconical antenna (with the 10 dB attenuator installed) to a signal source. Use the coaxial cable that is used for regular product testing to connect the receiving antenna to the EMI receiver or spectrum analyzer via a 10 dB attenuator that shall be installed directly onto the input port of the EMI receiver or spectrum analyzer.

c) Scan the receiving biconical antenna from 1 m to 4 m while simultaneously scanning or stepping the EMI receiver or spectrum analyzer over the frequency range 30 MHz to 200 MHz. Use a maximum resolution bandwidth of 120 kHz. Use either linear frequency steps with maximum step-size equal to one-half of the chosen resolution bandwidth, or use a linear scan. Confirm that the received signal is at least 20 dB above the system noise floor. Record the maximum received signal levels. The results recorded are the reference values for the two biconical antennas at 10 m in horizontal polarization and are designated as $S_{21,\mathrm{BB10H}}$.

d) Without moving the transmit biconical antenna, remove the receiving biconical antenna and replace it with the hybrid antenna to be qualified, such that the reference point on the hybrid is at the 10 m distance, as measured from the reference point of the transmit biconical antenna. If required or desired in accordance with N.3 c), install the hybrid antenna impedance matching pad (HAIMP) attenuator at the output connector of the hybrid antenna. Designate the insertion loss of the HAIMP as L_{HAIMP}.

e) Reconnect the receiving coaxial cable, and repeat step c), making certain that the EMI receiver or spectrum analyzer settings are not changed. The results are the "antenna under test" (AUT) values of the transmit biconical antenna and the receiving hybrid antenna at 10 m in horizontal polarization. These results are designated as $S_{21,\mathrm{BH10H}}$.

f) Calculate the reference and AUT horizontally polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB10H}} = S_{21,\mathrm{BB10H}} + FSAF_{\mathrm{biconical}} \tag{N.7}$$

$$E_{\mathrm{BH10H}} = S_{21,\mathrm{BH10H}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \tag{N.8}$$

g) Calculate the difference between the reference and AUT horizontally polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{10mH}} = E_{\mathrm{BB10H}} - E_{\mathrm{BH10H}} \tag{N.9}$$

h) Compare the ΔE_{10mH} results obtained in step g) with the acceptance criteria given in N.5.2.

i) Repeat steps a) through h) with the biconical antennas and the hybrid antenna under test in vertical polarization at the 10 m measurement distance. Denote the reference and AUT vertically polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB10V}} = S_{21,\mathrm{BB10V}} + FSAF_{\mathrm{biconical}} \tag{N.10}$$

$$E_{\mathrm{BH10V}} = S_{21,\mathrm{BH10V}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \tag{N.11}$$

j) Calculate the difference between the reference and AUT vertically polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{10mV}} = E_{\mathrm{BB10V}} - E_{\mathrm{BH10V}} \tag{N.12}$$

k) Compare the ΔE_{10mV} results obtained in step j) with the acceptance criteria given in N.5.2.

Change N.5 as follows:

N.5 Acceptance criteria

N.5.1 Criteria for hybrid antennas to be used at the 3 m measurement distance

In the frequency range 30 MHz to 200 MHz, for a given polarization, at the 3 m measurement distance, on a specific test site, a hybrid antenna shall be deemed acceptable for use in making final compliance measurements if the difference in results of measurement performed in accordance with N.4 at each polarization meets the following requirements:

— The results of the ΔE_{3mH} calculations are greater than or equal to −2.5 dB and less than or equal to +2.5 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive); and,

— The results of the ΔE_{3mV} calculations are greater than or equal to −2.5 dB and less than or equal to +2.5 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive).

NOTE—The above criteria are based upon the expanded uncertainty values for a k = 2 coverage factor that were calculated for the exact measurement procedure (at the 3 m measurement distance) detailed in N.4.3.1 steps a) through k) of this annex.

N.5.2 Criteria for hybrid antennas to be used at the 10 m measurement distance

In the frequency range 30 MHz to 200 MHz, for a given polarization, at the 10 m measurement distance, on a specific test site, a hybrid antenna shall be deemed acceptable for use in making final compliance measurements if the difference in results of measurement performed in accordance with N.4 at each polarization meets the following requirements:

— The results of the $\Delta E_{10\mathrm{mH}}$ calculations are greater than or equal to −2.4 dB and less than or equal to +2.4 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive); and,

— The results of the $\Delta E_{10\mathrm{mV}}$ calculations are greater than or equal to −2.4 dB and less than or equal to +2.4 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive).

NOTE—The above criteria are based upon the expanded uncertainty values for a $k = 2$ coverage factor that were calculated for the exact measurement procedure (at the 10 m measurement distance) detailed in N.4.3.2 steps a) through k) of this annex.

Annex O

(informative)

Bibliography

Insert the following citations in the Bibliography (Annex O). (Cross-references to each citation can be found in F.6.1, Introduction, D.1, and D.2.4, respectively.)

[B52] Hart, M. J., Bronaugh, E. L., and Osburn, J. D. M., "Obtaining FCC approval for submission of GTEM data," *IEICE International Symposium on Electromagnetic Compatibility*, Sendai, Japan, p. 797, 1994.

[B53] CISPR 32:2015, Electromagnetic compatibility of multimedia equipment – Emission requirements.

[B54] Chen, Z., "Understanding geometry specific correction factors in ANSI C63.5," *Asia-Pacific International Symposium on Electromagnetic Compatibility*, Beijing, China, pp. 561–564, 2010.

[B55] ANSI C63.7-2015, American National Standard Guide for Construction of Test Sites for Performing Radiated Emission Measurements.

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